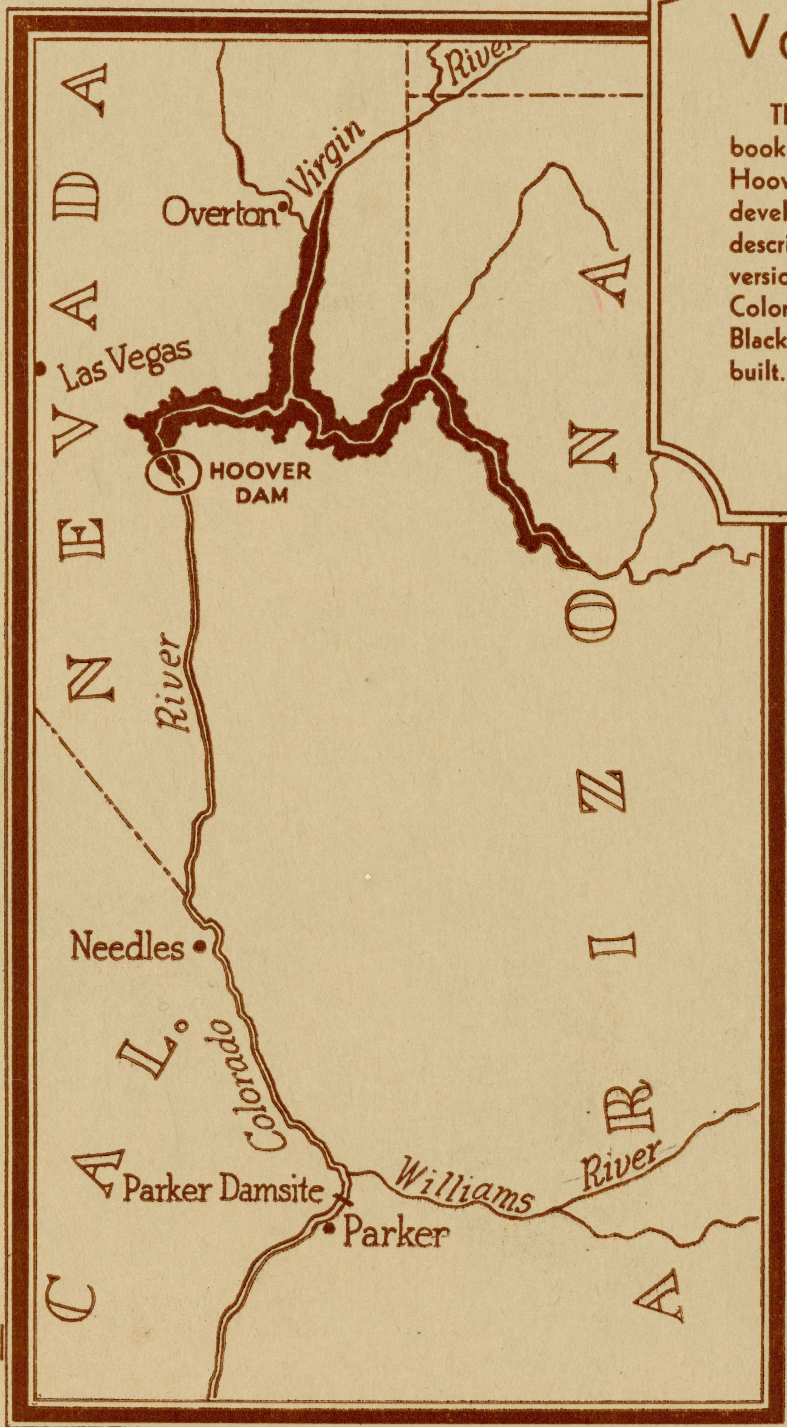


The Story of the Hoover Dam

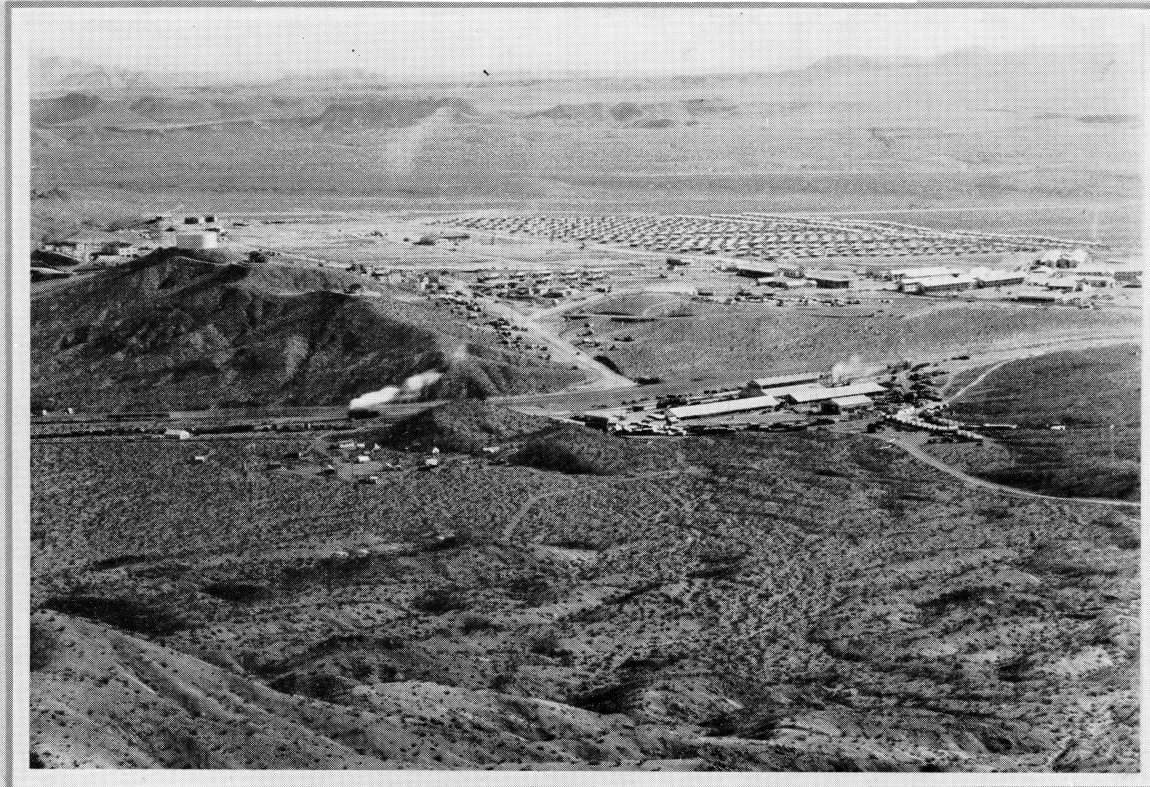
Volume Two

This is volume two of a series of booklets on the construction of the Hoover Dam. It covers the early development of Boulder City and describes the driving of the four diversion tunnels which will carry the Colorado River through the walls of Black Canyon while the dam is being built.

Ingersoll-Rand Co.

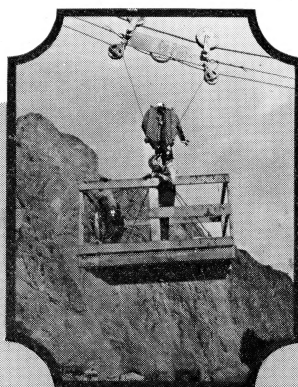


THE SECOND SUMMER

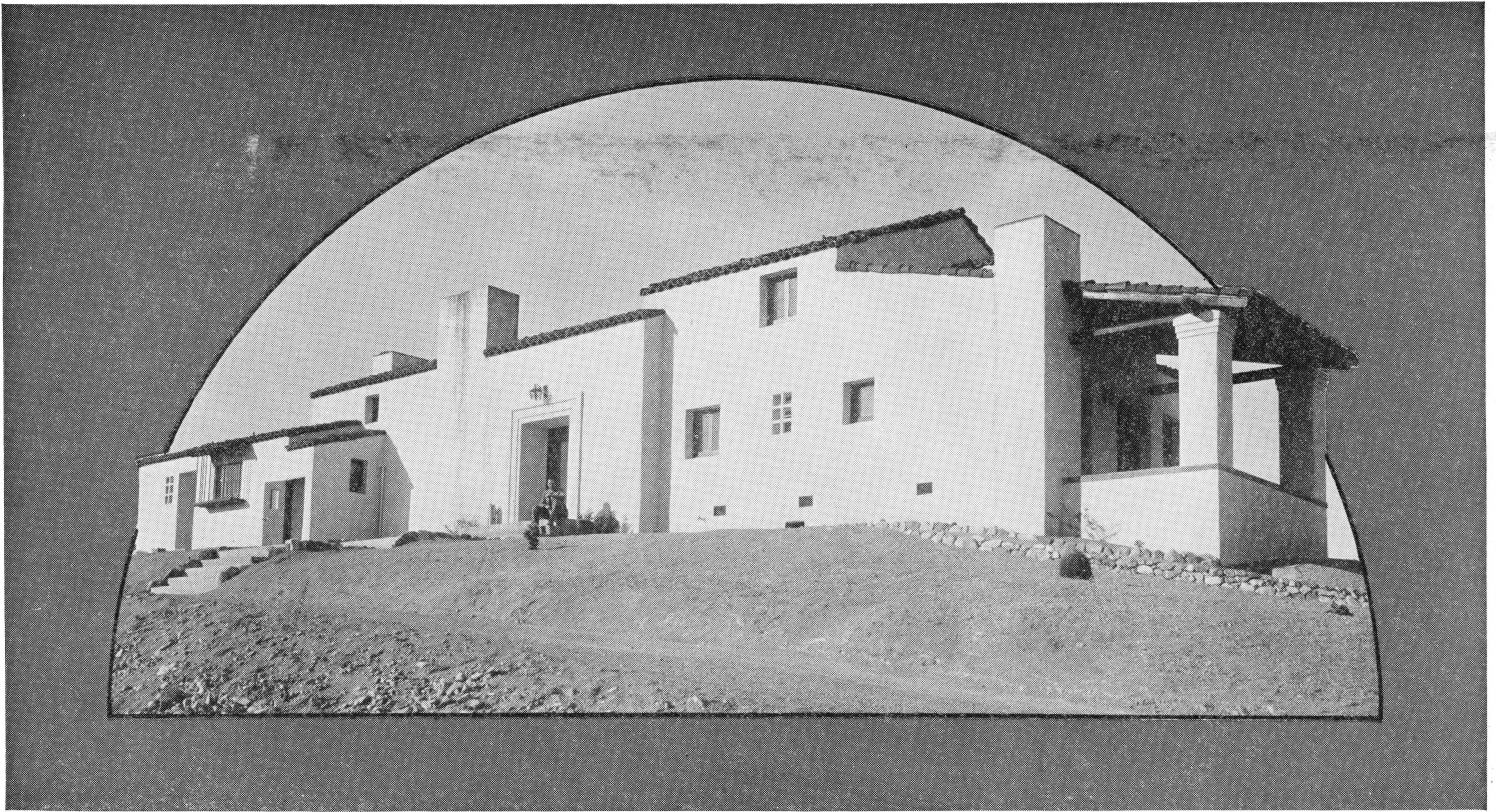


THANKS to the foresight of Uncle Sam and the contractors, Hoover Dam workers and their families are fairly comfortable during the hot-weather period that will reach its climax this month. Boulder City, a \$2,000,000 model municipality, affords every possible protection against the blistering heat that hovers over the desert for five months each year. Nearly 5,000 persons live in this de luxe construction camp which has risen in a waste of sand.

Volume Two



July, 1932



This attractive Spanish-type building is the home of the directors of Six Companies Incorporated during their frequent visits to the work. It also serves as a guest house.

Construction of the Hoover Dam

How the Contractors Handled the Huge and Costly Program of Preliminary Work

C. H. VIVIAN

DESPITE the unprecedented size of the Hoover Dam contract, the multiplicity of operations involved, and the comparative isolation of the site, Six Companies Incorporated organized its forces and entered upon its huge task in surprisingly short time. Formal notification by the Government to begin work was not given until April 20, 1931, following the actual signing of the contract by Secretary Wilbur of the Department of the Interior. The contractors did not stand on ceremony, however, and little more than a week after the opening of bids at Denver, on March 4, Supt. F. T. Crowe was on the ground recruiting a labor crew to carry on the initial stages of the 7-year job and at the same time making ready for subsequent operations. First of all he opened an office at Las Vegas, Nev., roughly 30 miles from Black Canyon. Then he visited the site where the construction town of Boulder City was to rise and started a battalion of men building quarters for the army of workers that was to follow.

The speed with which Six Companies Incorporated inaugurated work is characteristic of the zeal and industry which have since been shown. At the very outset, the gigantic undertaking was resolved into its various major factors and every phase of the work that could be started was got underway with the least possible delay. By June, 700

men were at work, and the payroll was \$100,000 monthly. Almost over night the desert quiet was transformed into teeming activity. A 3-shift day and a 7-day week were put into effect as soon as the working forces had been fairly organized, and that schedule was adhered to month after month almost without a break. Neither the sizzling summer heat nor the advent of legal holidays was

allowed to slow things up. As a result of this vigorous program, remarkable progress has been made during the first year of operations. If maintained, and there seems to be every reason that it will be, it is bound to bring about completion of the contract well ahead of the time limit set.

It is safe to say that never before has there been a project which required so much preliminary work before the real purpose of accomplishment could be attacked. While no official figures are available on the point, a member of the Six Companies organization has estimated that approximately \$2,000,000 was spent before a shovelful of "pay dirt" was turned over. This huge sum, which had to be expended merely to prepare the way for performing the principal work involved, is in itself sufficient to carry out a complete contract of no mean size.

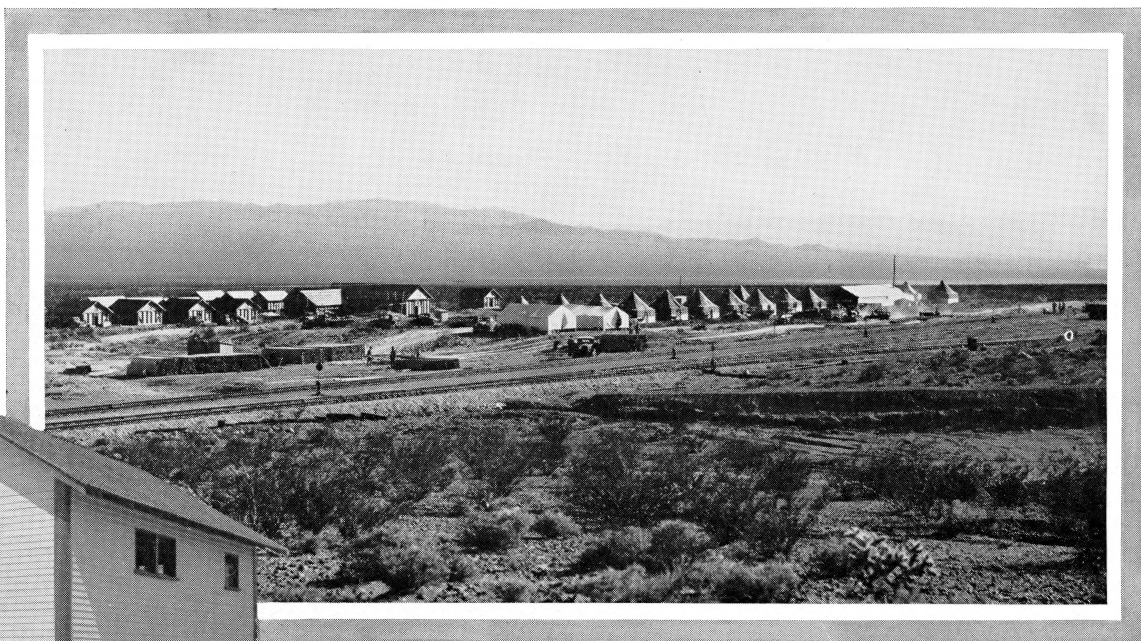
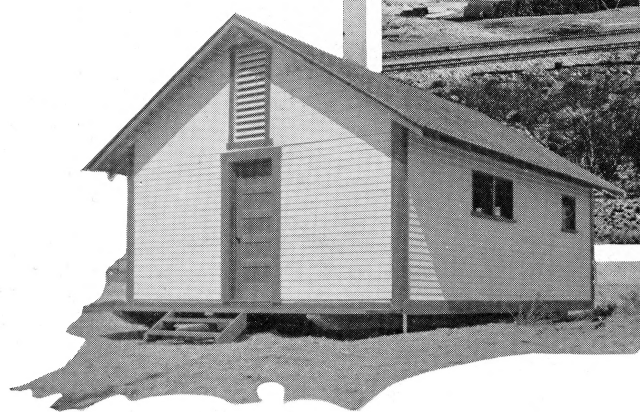
The advance guard of dam builders was greeted by a desolate region of no buildings and few roads, populated principally by little vari-colored lizards and an occasional jack-rabbit. The arid climate and the sandy soil combine to limit the vegetation to little other than mesquite and cacti, and one might travel mile upon mile without seeing a tree. Roughly 1,400 feet below the general level of this barren expanse, the temperamental Colorado River, red and roily, has cut a serpentine



W. A. Bechtel, president of Six Companies Incorporated.



Three views of typical structures among the 475 buildings erected by Six Companies Incorporated in Boulder City. Top—The \$50,000 hospital. Center—Two of the 172-man dormitories, of which there are eight. Bottom—A row of 3-room houses for married workers and their families.



When Boulder City was young. Carpenters living in the tents shown above built 40 eight-man bunk houses on skids. At the right is a close-up of one of the bunk houses.

course. At Black Canyon it is hemmed in by sheer walls of igneous rock 600 feet high: above the canyon the basin widens to a 12-mile span from rim to rim.

From the outset, there was no attempt to compromise with nature. "We must have a place to eat and sleep before we can put men out there", Superintendent Crowe stated. Accordingly, the first plans unrolled were those for a construction camp. The canyon bottom near the dam site was virtually inaccessible at the time except by boats; moreover, it was a veritable inferno in summer. The Government had wisely selected a site seven miles from the river on the Nevada side for a base of operations. Here it was that Six Companies Incorporated pitched camp and formed the nucleus of Boulder City—the fastest growing town America has known since the era of the gold rushes. During the intervening period of less than twelve months, the contractors have spent upwards of \$800,000 for the construction of more than 475 buildings, practically every one of which will be torn down as soon as the dam is completed. This because Uncle Sam hopes to mold a model municipality there. Details of its physical and political make-up and the part that the Government is playing in its development will be presented in a later article. It is our present purpose to sketch, in a broad way, the steps that the contractors had to take by way of approaching the main task in hand, and to set down some of the things that were done to bring a measure of comfort to the workmen in a section of trying climatic restrictions.

At the time the Six Companies forces appeared on the ground, the Union Pacific Railroad was completing a 22-mile branch from a point near Las Vegas on its Salt Lake City-Los Angeles line to the site of Boulder City. Meanwhile, construction was in

progress on both a railroad and a highway extending from Boulder City to the edge of the Nevada canyon wall above the top of the projected dam, the Government having let contracts for these in January.

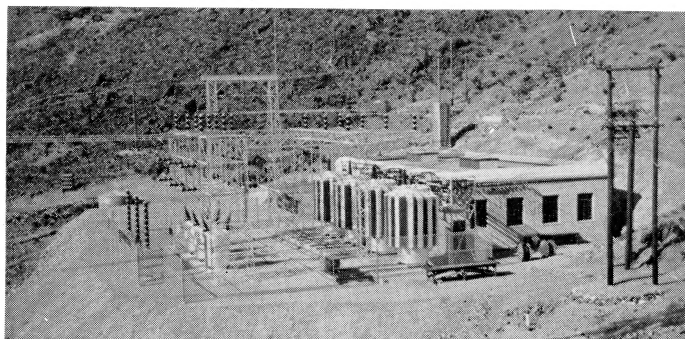
The building of the 10½-mile railroad was in the hands of the Lewis Construction Company, of Los Angeles, whose bid of \$455,509.50 was the lowest of the sixteen submitted. The line traverses a rough section which called for a ruling grade of 3 per cent and a maximum of 5 per cent. Its construction involved the moving of 900,000 cubic yards of earth and 202,000 cubic yards of rock, as well as the boring of five tunnel sections aggregating 1,705 feet in length and requiring the excavating of 26,000 cubic yards of rock. The tunnel work was done by Joe Gordon of Denver. The contract specified completion within 200 days from the beginning of work.

The contract for the gravel-base, oil-surfaced highway, 22 feet wide and 43,972 feet long, was let to the General Construction Company of Seattle, Wash., which gave a subcontract to R. G. LeTourneau, Incorporated, of Stockton, Calif. The work entailed the handling of 107,000 cubic yards of common excavation and 228,000 cubic yards of rock. Incidentally, something of a record was made in getting started on this work.

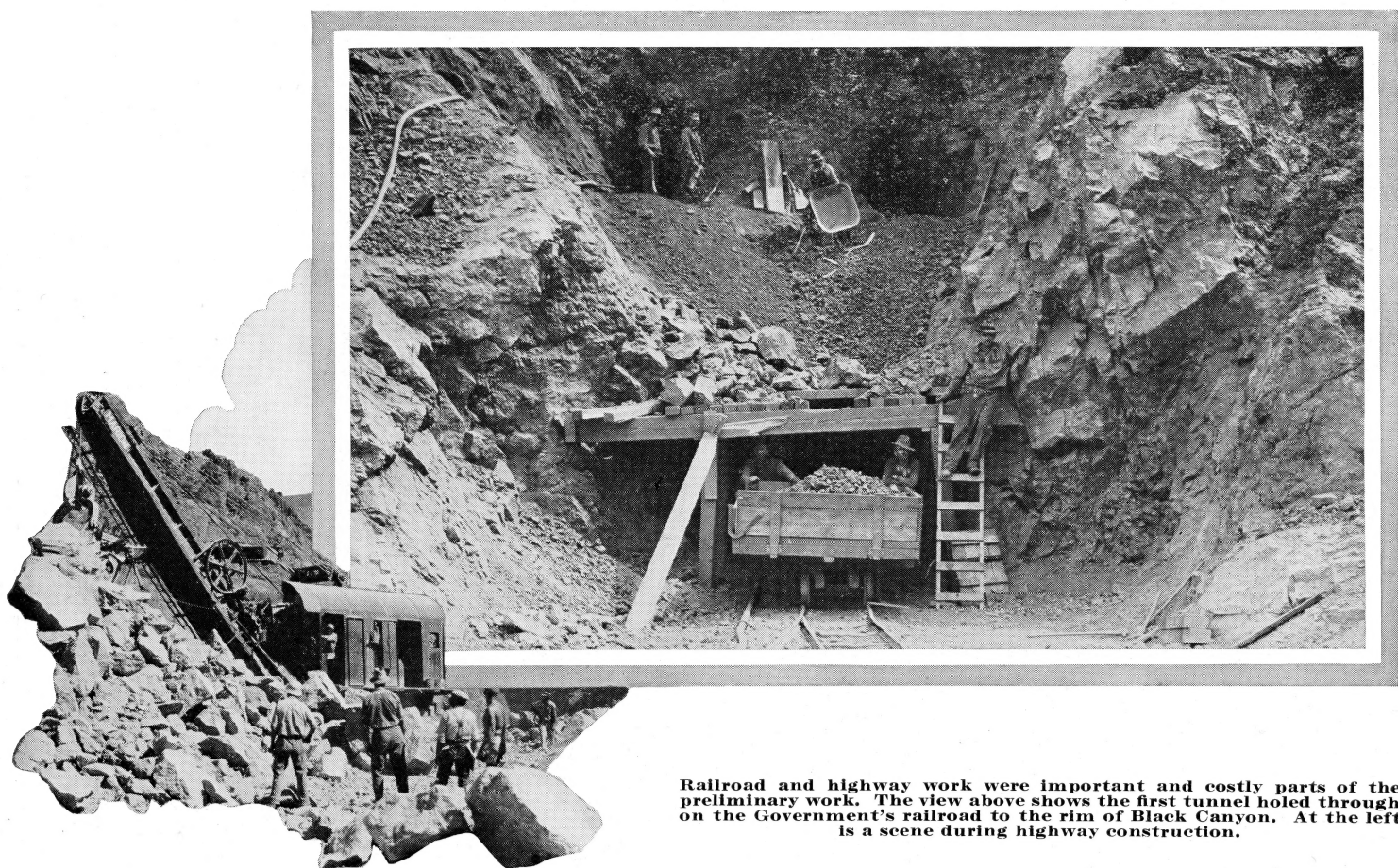
Two days after the contract was let it had been transferred to LeTourneau, Incorporated. Operations were started four days later, on January 28. On January 30, the Anderson Brothers Supply Company of

Los Angeles had facilities ready to care for 100 men. By February 7, fifteen carloads of machinery and equipment had been delivered, including fifteen Caterpillar tractors and two Ingersoll-Rand portable air compressors.

Through the instrumentality of the Government, work was also underway on another very important medium of service to the contractors. This was a transmission line to deliver power to the site from generating stations at Victorville and San Bernardino, Calif., the latter more than 200 miles away. The contract for furnishing power was awarded jointly to the Southern Sierras Power Company and the Nevada-California Power Company. The line, together with a substation near the rim of the canyon on the Nevada side, was designed and constructed by the first-named company at a cost of approximately \$1,500,000. Here, again, unusual speed was shown in the face of many obstacles. Despite the fact that a considerable portion of the route was across mountainous country, the 193-mile line from Victorville to the substation was put in place at the rate of 1.45 miles a day, which is said to constitute a



The substation which serves as a distributing center for the many electrical lines.



Railroad and highway work were important and costly parts of the preliminary work. The view above shows the first tunnel holed through on the Government's railroad to the rim of Black Canyon. At the left is a scene during highway construction.

record for such work. Field camps for from 50 to 80 men each were established at suitable intervals, and as many as five of them were maintained at a time. In some cases the trucks that delivered materials and supplies had to make their own roads; and on one occasion it was necessary to let a truck down a steep grade by means of a winch and cable. Construction activities extended over a distance of 125 miles at one time. The line consists of 2-legged, fabricated-steel towers with 34-foot, steel, angle cross arms, spaced seven to the mile. Approximately 5,000,000 pounds of steel and 1,080,000 pounds of aluminum-strand, steel-reinforced cable were used. A telephone line parallels the power line.

Construction of the substation on a high, rocky point having a steep approach was accompanied by difficulties. A compressor to furnish air for excavating the 2,100 cubic yards of rock required to be moved for the placing of foundations was packed up the hillside in sections by burros. Later a temporary switchback road, having grades up to 17 per cent, was built to permit the moving in of construction materials and station equipment. Power was turned on on June 25, beating by several days the time limit of 240 days allowed for designing and building the system. R. H. Halpenny was in charge of design and E. J. Waugh was construction engineer. Field forces on line construction

were in charge of C. H. Rhudy; and H. O. Watts supervised the building of the substation. The line is insulated for 132,000 volts, but power is being transmitted at 80,000 volts. A 6.83-mile, 33,000-volt, wood-pole line was built from the substation to Boulder City, and a .73-mile, 2,300-volt line was constructed into the canyon to furnish power to the No. 1 pumping station of the water-supply system for Boulder City.

As previously written, the first concern of Six Companies Incorporated was to provide adequate living quarters for their personnel. In this connection it should be emphasized that the ends to which the contractors have gone to minister to the general comfort and well-being of their employees is without precedent in American contracting annals. In a sense, the Hoover Dam project is not only a construction job but also a sociological venture.

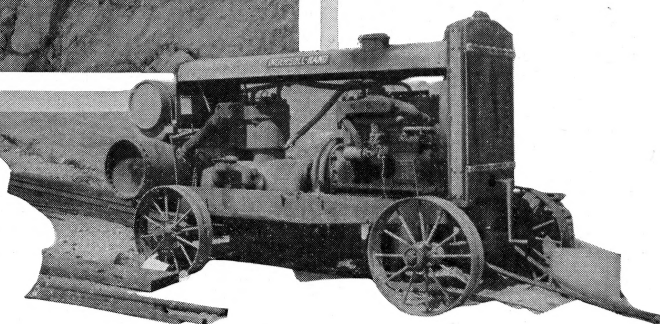
A tent colony, served with water from tank cars, housed the workmen who founded Boulder City. These men quickly put together forty 8-man frame houses, built on skids to facilitate their movement later on. A brigade of carpenters, plumbers, and other artisans occupied these houses as soon as they were ready, and proceeded to erect the contractors' permanent camp—the most extensive array of buildings ever assembled in connection with a construction job in this

country. The contract provides that 80 per cent of the contractors' employees must live in Boulder City; and, in laying out the town, the Government allotted certain portions to the contractors for building purposes. A rental of \$5,000 a month is paid for the use of this land.

Eight dormitories for single men, each two stories high and capable of housing 172 persons, have been built. They are in the form of a letter H, with shower baths and toilets in the central section. A large, screened porch runs the length of the building on each floor. A unique feature is the provision of individual rooms, 7x10½ feet, for each man. A large building houses the general offices of Six Companies Incorporated, in which are grouped the executive, accounting, purchasing, and engineering staffs. Adjacent to it is a dormitory for unmarried office employees, with one end made into a clubroom. Close to the structures previously mentioned are the mess hall, with a seating capacity of 1,000, and a modern laundry. A separate dormitory is provided for the 75 mess-hall employees. Another large structure serves as a recreation center. It contains billiard tables, a soda fountain, a barber shop, a news stand, and other features. A well-defined recreational and sports program is carried on under the direction of Frank Moran, former contender for the heavyweight boxing championship of



Avast amount of scaling and other work involving "Jackhamer" drills was done on the canyon walls during the early operations. At the right is one of the eighteen I-R portable compressors used before stationary air-producing plants were installed.



the world. A commissary, which is in reality a department store, occupies a large building. Fixtures, built especially for the purpose, and furnishings of the most modern type make attractive the interior, which is divided into sections which retail every conceivable item of merchandise at prices which compare favorably with those asked for similar classes of goods in Los Angeles. All major buildings are equipped with water-washed air-conditioning plants and air-distribution systems which make it possible to cool or heat them as desired. Four central heating plants will be utilized in winter months. Electric water coolers are installed in all principal buildings.

Individual cottages, each placed on a 50-foot lot, are provided for renting to married employees and their families. Each cottage is supplied with electricity for lighting, flasks of high-pressure gas for cooking, and fuel-oil stoves for heating. It might be noted here that Boulder City is as near a smokeless town as exists. Up to February 1 of this year 396 such cottages had been built, consisting of 260 two-room and 136 three-room units. There are also eleven 5- and 6-room houses for construction officials and two larger residences for Superintendent Crowe and company executives.

In addition to these buildings are suitably situated warehouses, a garage, machine shop, etc. The machine shop, a steel frame struc-

ture, is completely equipped to handle repairs on machinery of all classes used on the job, ranging in size up to locomotives and huge power shovels. Compressed air is furnished by an Ingersoll-Rand Type 20 compressor of 316 cubic feet per minute piston displacement. Included in the shop equipment are several I-R air hoists. There is also an air-operated forging hammer.

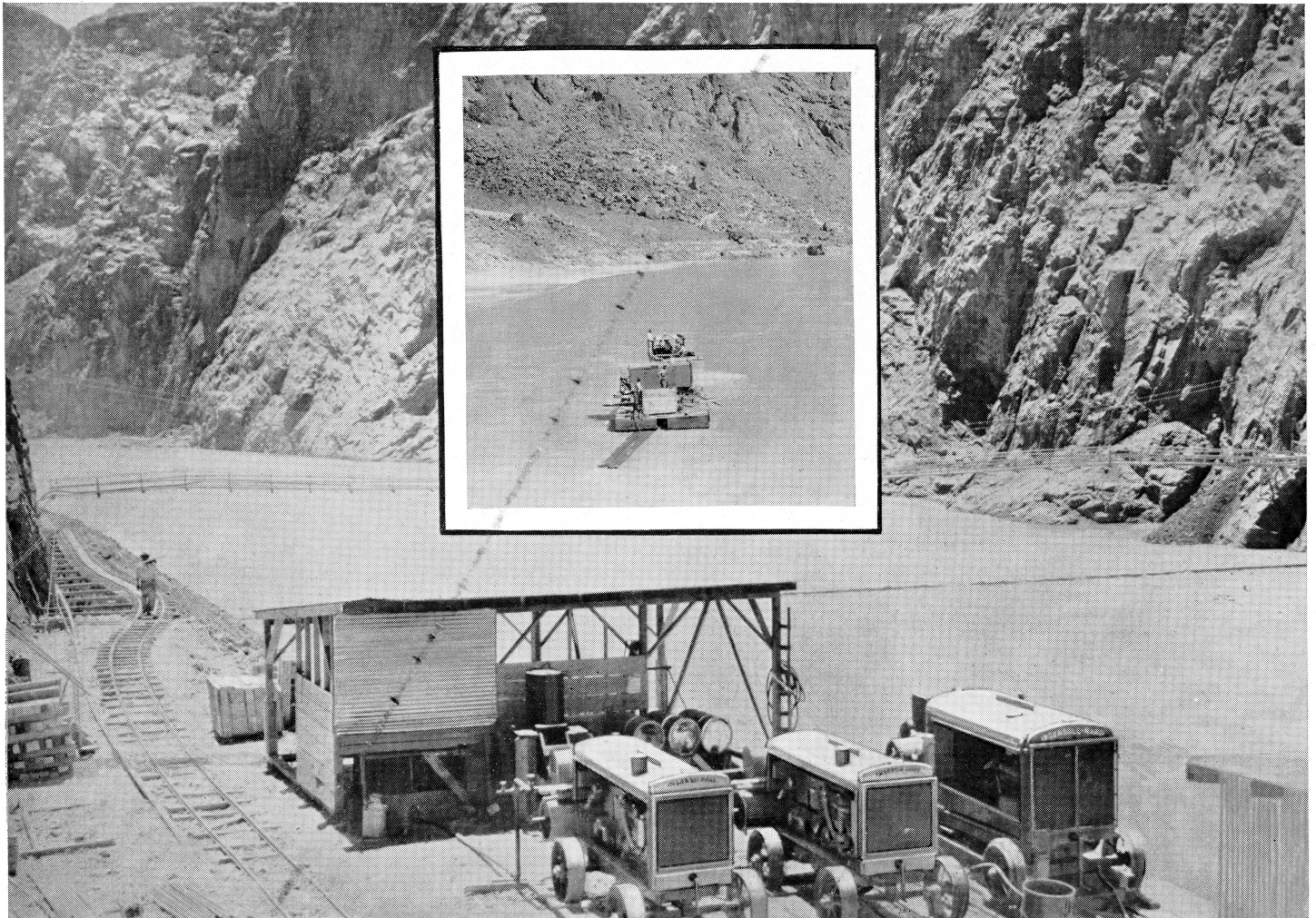
A modern hospital of brick construction and containing \$30,000 worth of equipment is designed to become a permanent feature, as it will probably be taken over by the Government upon completion of the contract. It offers every service that can be obtained in the average large city hospital. Twenty beds are now provided, with plans underway to add ten more.

The building program was in charge of the Boulder City Company, a subsidiary organized to direct feeding, housing, and transporting operations. V. G. Evans serves as its manager. George de Colmesmil of San Francisco was the architect. With a few exceptions the buildings have frames of wood, with stucco on the outside and wall board on the inside. Roofs are of asbestos shingles.

The high standard of food served has occasioned comment by all who have visited the job. The mess hall is undoubtedly the finest of its kind ever built for similar purposes. Two large dining rooms, equipped with

facilities that savor more of a high-class restaurant than of a contractor's camp, are arranged on either side of a commodious kitchen that is outfitted in the most up-to-date manner. Ingenious machines to aid and improve the preparation of meals abound. Ranges fired by electricity, oil, and gas are available for cooking. Refrigerating rooms are provided for the preservation of meats, vegetables, and other foodstuffs. Incoming supplies are delivered direct from railroad cars or trucks by monorail.

The mess hall is operated under contract by the Anderson Brothers Supply Company, an organization of vast experience in shipyard and movie-location feeding. The finest foods obtainable are served, and there is a wide choice at each meal. Milk—500 gallons of it a day—comes by truck 80 miles from a 160-acre farm which was purchased especially as a source of supply. Last Thanksgiving the dam workers consumed, among other items, 2,400 pounds of turkey, 300 gallons of oyster soup, 300 pounds of cranberries, 760 pies, half a ton of plum pudding, and a quarter ton of candy at the principal meal. Everybody, from the highest executive to the lowliest laborer, eats the same food in the same dining room. Meals are served at six separate times during the 24 hours to accommodate the men on the various shifts. Workers going down to the canyon carry with



A battery of I-R portable compressors supplying air for beginning one of the four diversion tunnels. The insert illustrates how these machines were floated down the river to points of work before roads were built.

them a lunch which they select themselves in cafeteria style. An auxiliary camp is maintained at Cape Horn, two miles above the dam site on the river's edge. Six dormitories, each accommodating 80 men, a mess hall, commissary, and recreation room are provided there. They are similar in construction to the buildings at Boulder City.

The building program which has been described extended over a period of many months—in fact, is still going on. Principal structures were, however, erected with great speed, and by the end of the summer accommodations were available for 2,000 men. But it should be remembered, that while the camp in its finished state will eclipse anything of its kind previously built, it lacked many things during the early months of the construction period. With the thermometer registering more than 100° in the shade for days at a time, living conditions were necessarily hard. The chief handicap was the absence, through no fault of the contractors, of an adequate water supply. Consequently, a bath was a real luxury. Then, too, the cooling system for the build-

ings had not yet been placed in operation. Despite these and other shortcomings, which affected alike the highest and the lowest, the spirit of the great majority of the men was admirable. The fine coöperation which was shown by the labor force during this pioneer stage of activities was one of the primary reasons that the contractors were able to "get the jump" on the job in hand. Many a disposition which was sorely tried was helped over the rough spots by the knowledge that Six Companies Incorporated was doing all that was humanly possible to provide a maximum of comfort and convenience at the earliest possible moment.

Even while housing activities were in their infancy, the contractors plunged into the task of opening up operations in the canyon. This involved many things. The whole method of attack had to be decided upon, and an organization set up to handle each of the countless phases in its turn and to coördinate all of them. Surveys had to be run and plans drawn. Equipment of every conceivable kind, running from nails to trucks,

had to be purchased and got on the job as quickly as practicable.

Of immediate concern was the matter of making the river bottom accessible to men and machinery. A 2-mile highway had to be hewn from virtually solid rock to connect the end of the Government road with the water level at a point near the site of the diversion tunnel outlets on the Nevada side, about half a mile below the dam site. At the upper end of the canyon, Hemenway Wash provided a natural approach to the river at a point some two miles above the dam site. From there a road, again mostly through rock, had to be constructed downstream along the base of the cliff to give access to the sites of the upper portals of the diversion tunnels on the Nevada side. Some 30 miles of power lines had to be run from the substation to various points in the canyon to serve electric shovels, electric-driven compressors, pumps, tunneling machinery, etc., and to furnish current for lights within the tunnels and outside flood lights for night work. A number of suspension foot bridges had to be thrown across



S-49 "Jackhammers" excavating at the base of a cliff in the canyon for a bridge anchorage. A group of "cherry pickers", carrying on their hazardous task of scaling a canyon wall, is shown in the insert.

the river to provide means of reaching the Arizona side with men and materials.

Location surveys had to be run and work started on some 21 miles of standard-gage railroad to connect the Government line with various portions of the work. The line takes off of the Government railroad to the dam site about half way from Boulder City and runs by a winding route, to secure grade, to a point in Hemenway Wash designated as Junction City. Here, at an elevation of 1,015 feet—75 feet above the high-water line of the reservoir that will be created by 1936—will be located the gravel screening and washing plant and the stock pile of aggregates for the concrete that will go into the dam. From Junction City a branch extends upstream to the Arizona gravel deposits and another branch downstream to reach the dam site at an elevation of 720 feet. The last-named section will deliver concrete for pouring the first stages of the dam.

When concreting operations are at their height, this railroad will carry a volume of traffic heavier than that on any main line

in the country. Just for transporting the 5,000,000 cubic yards of gravel that will go into the concrete for the dam it will require the equivalent of a 1,300-mile train of freight cars each loaded with 100,000 pounds. Sixteen miles of grading on this railroad work was contracted to the John Phillips Company, and the track laying was contracted to Shannahan Brothers. Six Companies forces undertook the building of the 5-mile section from Junction City to the dam site. Two miles of this work was in the solid rock of the canyon wall, and much of it in tunnels or half tunnels.

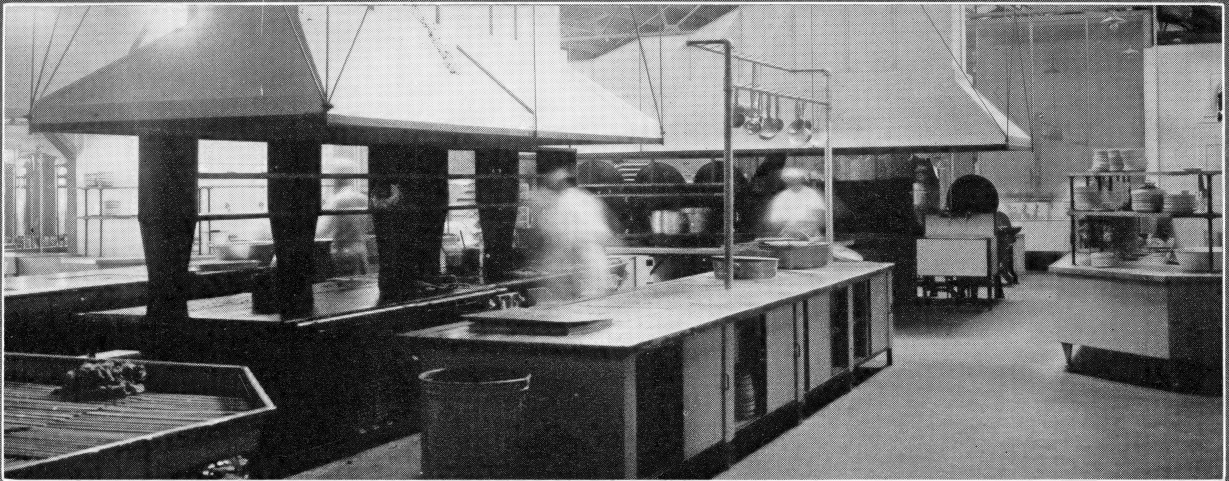
Another phase of the work which was started early was the scaling of loose or projecting material from the canyon walls. This cleaning off was done not only to clear sites for the numerous tunnel and adit openings but also as a measure of safety to protect workmen in the canyon bottom.

Compressed air played a vital part in essentially all these pioneer aspects of the construction. At one time eighteen Ingersoll-Rand Type 20 and Type XL portable compressors were in service by Six Companies Incorporated. Before the road reached the

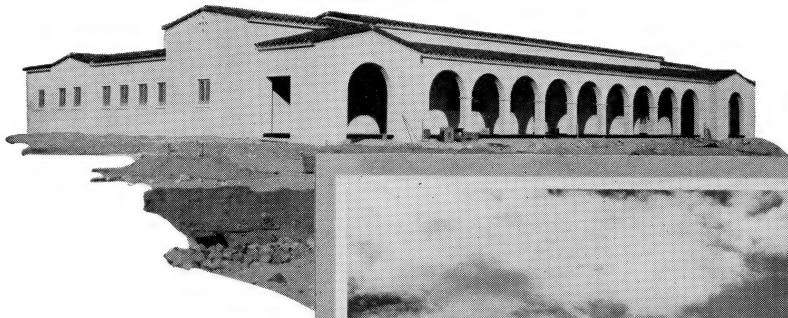
canyon bottom, barges were employed to float some of these machines downstream from a landing at Hemenway Wash to suitable locations. Incidentally, water transportation has solved the problem of reaching the many points of work which are inaccessible by roads. The contractors early put into service a fleet of motorboats which continue to be of great assistance and which likely will be used to a considerable extent throughout the life of the contract.

"Jackhammers" were indispensable tools in aiding the highway, railroad, and scaling operations, and later on in facing openings for the four diversion tunnels. The drill selected for all these purposes was the Ingersoll-Rand Type S-49.

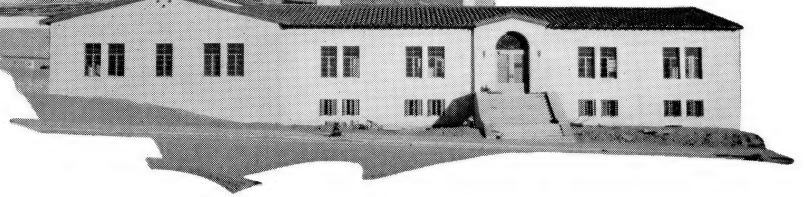
With the varied activities enumerated in progress and many other divisions of the work being started, the intensity of operations that prevailed can hardly be comprehended. During September, 1931, approximately 50 tunnels were in various stages of completion. Meanwhile, much Government work, which will be described in a later article, was also being vigorously prosecuted.



Good food and recreation for employees are considered important by the contractors. From top to bottom the pictures show: the recreation building and, at the right, the department store; a corner in the recreation building; a portion of the splck-and-span kitchen; one side of the 1,000-seat dining hall.



Three of the larger structures erected by the Government in Boulder City. The dormitory and guest house is shown above, the administration building in the center, and the post office below.



Construction of the Hoover Dam

Within a Year's Time the Government has Reared a Modern City in the Desert at a Cost of \$1,600,000

C. H. VIVIAN

BOULDER City Nev., is a municipal by-product of the Hoover Dam. Sired by Uncle Sam, and growing up under his watchful eyes, it is unique among American cities. A year ago the ground it occupies was desert waste. Today it is a community of more than 4,000 souls and some 600 buildings. It has paved streets, water, sewers, electric lights, and telephones. Soon it will have lawns, flower gardens, shade trees, and a park.

Even the Government is in doubt as to its ultimate size and prosperity; but its immediate future is assured by virtue of the clause in the Hoover Dam contract which requires 80 per cent of the employees of Six Companies Incorporated to live there during the construction period. After the dam is completed, nobody knows just what will happen. A certain number of Bureau of Reclamation men will be stationed there, and probably the employees of the power company that takes over the operation of the huge generating stations will also make it their home. As regards other permanent residents, the Government is only speculating; but it has reason to believe that the vast amount of publicity given the dam will draw homeseekers to the region and that the com-

pleted project will prove a magnet for tourists. At all events, the development plan visions an enduring town of 4,000 or 5,000 persons.

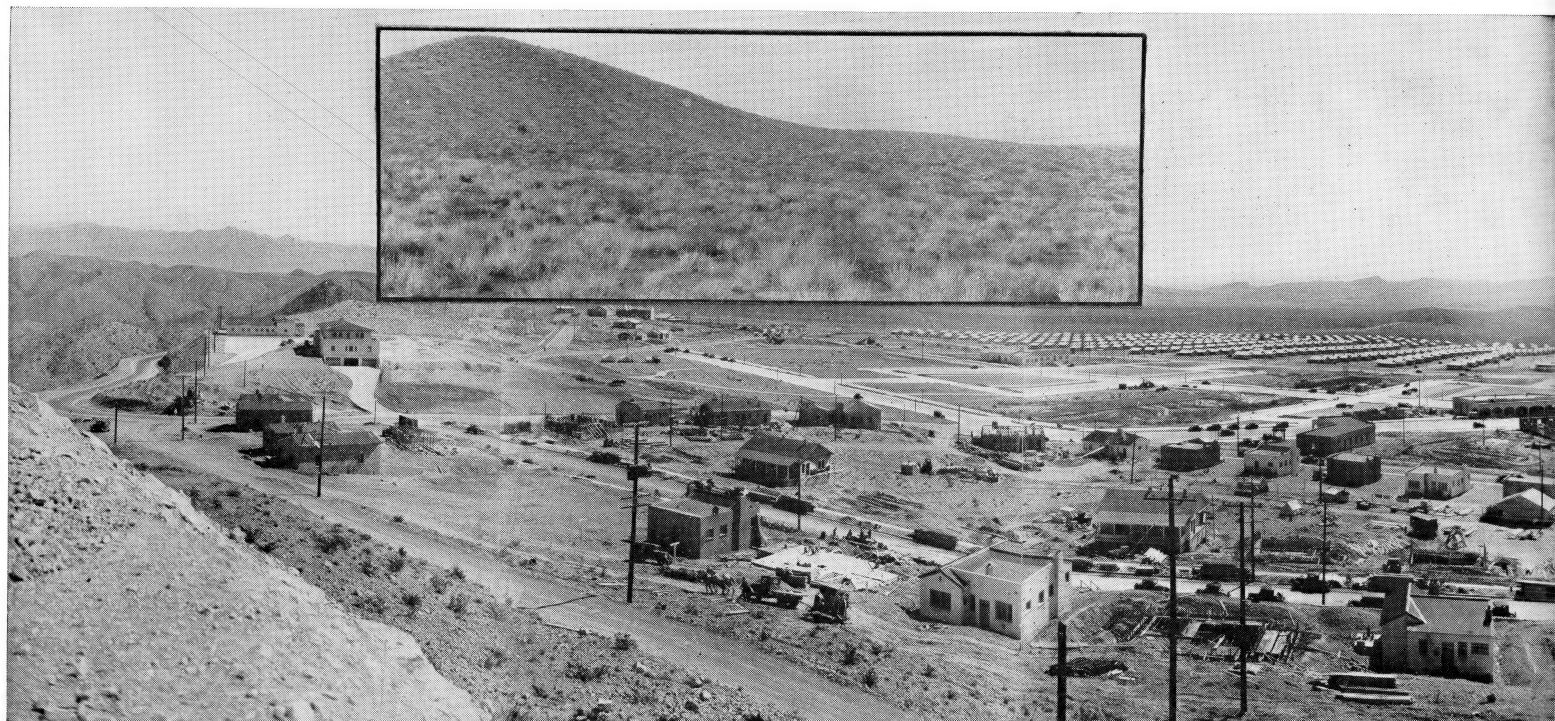
Boulder City is not the creature of whims or theories. It was born of sheer necessity. Bureau of Reclamation officials recognized that the Hoover Dam could never be reared in the midst of a desert unless precautions were taken to insure adequate care of the workmen. The bureau knew this because its own engineers had carried on in the blistering heat of many summers gathering the preliminary data required to locate and plan the structure now in the making. Their home was a cluster of tents which afforded little bodily or mental comfort. Fortunately, there were relatively few of them, and they managed to endure discomforts and to ward off pestilence. It would be out of the question, however, to house 3,000 men in this manner for six or seven years.

It would be a bit ironical, the Government thought, if the climatic restrictions proved too severe for American labor to carry through the largest single construction project it had ever attempted. And there were plenty of persons who predicted this would come to

pass. Some prophesied that Orientals would finally have to be imported to cope with the melting temperatures that prevail in Black Canyon for four months out of the year.

To make certain that nothing of this kind would happen, Uncle Sam decided to extend a kindly but firm paternal helping hand to the contractors and to set up a construction town under his control to insure for the workers a high standard of living and a maximum of comfort and general well-being. The wisdom of this course is shown by the marked effect it had on the attitude of bonding companies. Two of these concerns sent an investigator to the dam site before the contract was awarded. This emissary sizzled in the canyon one day and then took back his report. It was enough. The companies let it be known that they had no interest in underwriting the performance bond required of the contractors, despite the fact that the premium promised to exceed \$1,000,000. But when they learned the Government's plans for improving living conditions, they reconsidered the matter and ended by giving to the project a far lower rate than had been charged on many enterprises of smaller size.

The Government set aside \$2,000,000 for



Boulder City, as it appears from a hill to the north. In the foreground are residences for Government employees. At the extreme left are the administration building and the dormitory. The group of small buildings at the left center are residences of employees of Six Companies Incorporated. In line with them, at the right, are the contractors' dormitories,

the construction of Boulder City. Of this sum approximately \$1,600,000 had been spent or contracted for up to March 1, 1932. Great care was taken in selecting a site. A town in the canyon itself was out of the question. There wasn't room for one, and the terrific heat during a third of the year forbade it. Dr. Elwood Mead, Commissioner of the Bureau of Reclamation, summed up the situation in the following words:

"In the summer the wind that sweeps over the gorge from the desert feels like a blast from a furnace. At the rim of the canyon there is neither soil, grass, nor trees. The sun beats down upon the broken surface of lava rocks. At midday they cannot be touched by the bare hand. It is bad enough as a place to work. It is no place for a boarding house or a sleeping porch. Comfortable living conditions had to be found elsewhere, and these are found on the summit of the divide, seven miles from the dam site. Here there is fertile soil; here winds have an unimpeded sweep from every direction; here there is also an inspiring view of deserts and lonesome gorges and lofty mountains. When the dam is completed and a marvelous lake fills the foreground, the view from Boulder City will be so inspiring and wonderful as to be worth traveling around the world to see." The city site has an average temperature lower than that at any of the others considered and several degrees lower than the temperature at the dam site. It is 2,500 feet above sea level, 1,700 feet above the river, and 1,250 feet higher than the top of the future dam.

During the life of the Hoover Dam contract, Boulder City will be a municipality

with two distinct sections. It was told in a previous article in this series how Six Companies Incorporated has spent upwards of \$800,000 for buildings that will be razed when the dam is finished. In contrast to these temporary buildings, the Government is providing the permanent structures of the town. These include, aside from the site itself, the various utilities such as water and sewer systems and street lights, also sidewalks, paving, parks, public buildings, and permanent dwellings for its employees.

It was originally intended that Boulder City should be built largely in advance of the coming of the dam workers, who were to move into a spick-and-span town affording all conveniences. This plan was abruptly ended by the decision to speed up the dam contract to help alleviate the business depression. Thus it happened that when the contractors moved on to the job in March, 1931, the city was still in the blueprint stage. As a result, many hardships had to be borne during the first summer that adherence to the first plan would have averted. Happily, the next hot-weather period will find Boulder City better prepared for it.

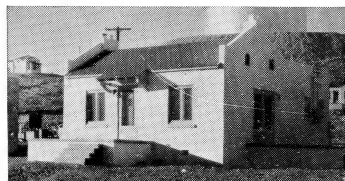
The town site includes approximately 300 acres, and is laid out roughly in fan shape with the point at the north, where a ridge separates it from Hemenway Wash. The northern portion is allotted to Government buildings. Groups of residences for Bureau of Reclamation employees are arranged along the lower slopes of the ridge on either side of the fan point.

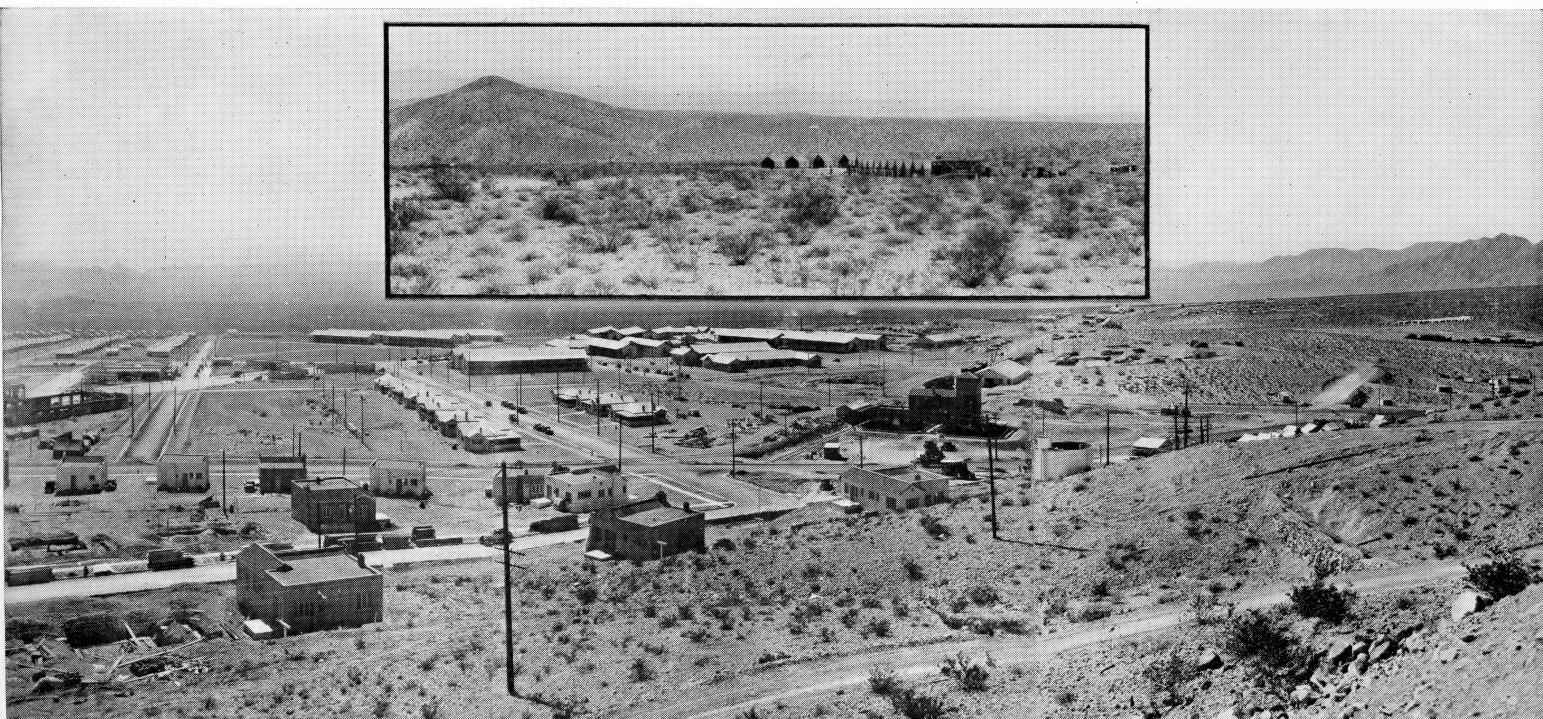
Between these two groups are the administration building and the dormitory. Just below these, to the south, is a 5-acre park at the apex of an angle formed by the meeting of two principal streets. These thoroughfares diverge to the far corners of the city at the south and form the chief arteries of travel, with most of the town site between them.

The ground has a fairly uniform slope of about 3° from north to south. The central portion of the city will be devoted to business and commercial uses; the southern section is set aside for residences. Considerable areas in this district are now occupied by temporary frame houses for employees of Six Companies Incorporated. Most of the contractors' larger structures, such as dormitories, store, recreation building, etc., are on the western edge of the town, where they do not impede development of the central part of the city.

Boulder City was laid out by S. R. DeBoer, a well-known city planner, and is designed to be a model town. In the business section are being provided special plazas for the parking of automobiles, and no street parking will be allowed. Alleys in the commercial zone are laid out 50 feet wide to permit the loading and unloading of trucks in the rear of stores and thus to lessen their use of street space. Through automobile traffic will travel on highways which are separate and distinct from the business and residential streets. Streets will be graduated in width according to their intended usage. Through highways and business streets will be 92 feet wide, and residential streets 60 feet wide.

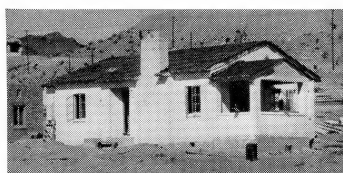
In the districts which are expected to have





office buildings, etc. The business section of the city will be developed near the center, where the arcaded post-office building may be seen. The insert at the left shows the site of Boulder City as it looked early in 1931. The insert at the right shows the tent camp, near Boulder City, which was the home of the Government engineers until a few weeks ago.

the greatest density of population, the blocks are laid out 900 feet long and 260 feet wide. In their design, provision has been made for interior plazas which will contain small parks. These can be equipped with playgrounds for small children and with croquet lawns and horseshoe pitching courts for elderly persons. The older boys and girls and the young men and women of the future Boulder City will find recreational facilities in the community park in the form of football, baseball, tennis, and other sports which are being planned for their amusement.



The Government's program of building, which is now well advanced, includes a \$60,000 administration building, a \$45,000 municipal building and post office, a \$33,000 dormitory for unmarried workers and visitors, a garage and fire station, a schoolhouse, 100 residences of from three to seven rooms each for married employees, and several community garages. Durable materials such as brick, tile, and stucco are being used in the buildings, all of which follow the Spanish type of architecture. The larger structures have furnaces, and the administration building is equipped with an air-conditioning system. Landscaping, and the planting of trees and lawns, have been started. When completed, these various items will have cost some \$600,000.

During the past autumn and winter, the New Mexico Construction Company of Albuquerque, N. M., has been carrying out a \$300,000 contract covering the installation of water distribution and sanitary sewerage systems; the grading of streets, alleys, and automobile parking spaces; the laying of

concrete curbs and gutters and of concrete and gravel sidewalks; and the paving of certain streets and the surfacing of others. This work involved, among other operations, more than 23 miles of trenching for pipe lines, 151,000 cubic yards of excavating, and the laying of 90,000 square yards of asphaltic-concrete pavement.

One of the major tasks in connection with the building of Boulder City was the provision of an adequate supply of pure and palatable water. This was done at a cost of approximately \$500,000 by installing equipment to pump Colorado River water more than six miles, elevate it nearly 2,000 feet, remove the discoloring sediment it carries, soften it, and treat it chemically to render it thoroughly safe for human consumption. A supply of greater initial purity could have been obtained by driving wells to tap the artesian reservoir beneath Las Vegas and the adjoining area, but cost and economic studies indicated that the river water could be developed at less expense.

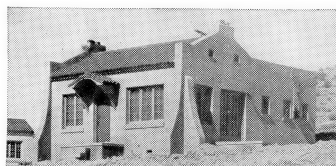
The intake is just below the outlets of the diversion tunnels, roughly half a mile below the dam site. Three centrifugal pumps elevate the water about 100 feet to a 200,000-gallon pre-sedimentation clarifier. The pumps are mounted on a car which may be lowered or raised on rails of 47° slope, making it possible always to take water from a zone 4 feet beneath the surface, regardless of the stage of the river flow. Most of the sediment settles out readily, and the retaining of the water up to three hours in

the pre-sedimentation basin serves to remove about 95 per cent of the solid matter. A Dorr traction clarifier mechanism, having a capacity of 62 tons of dry solids a day, removes the sludge which settles out.

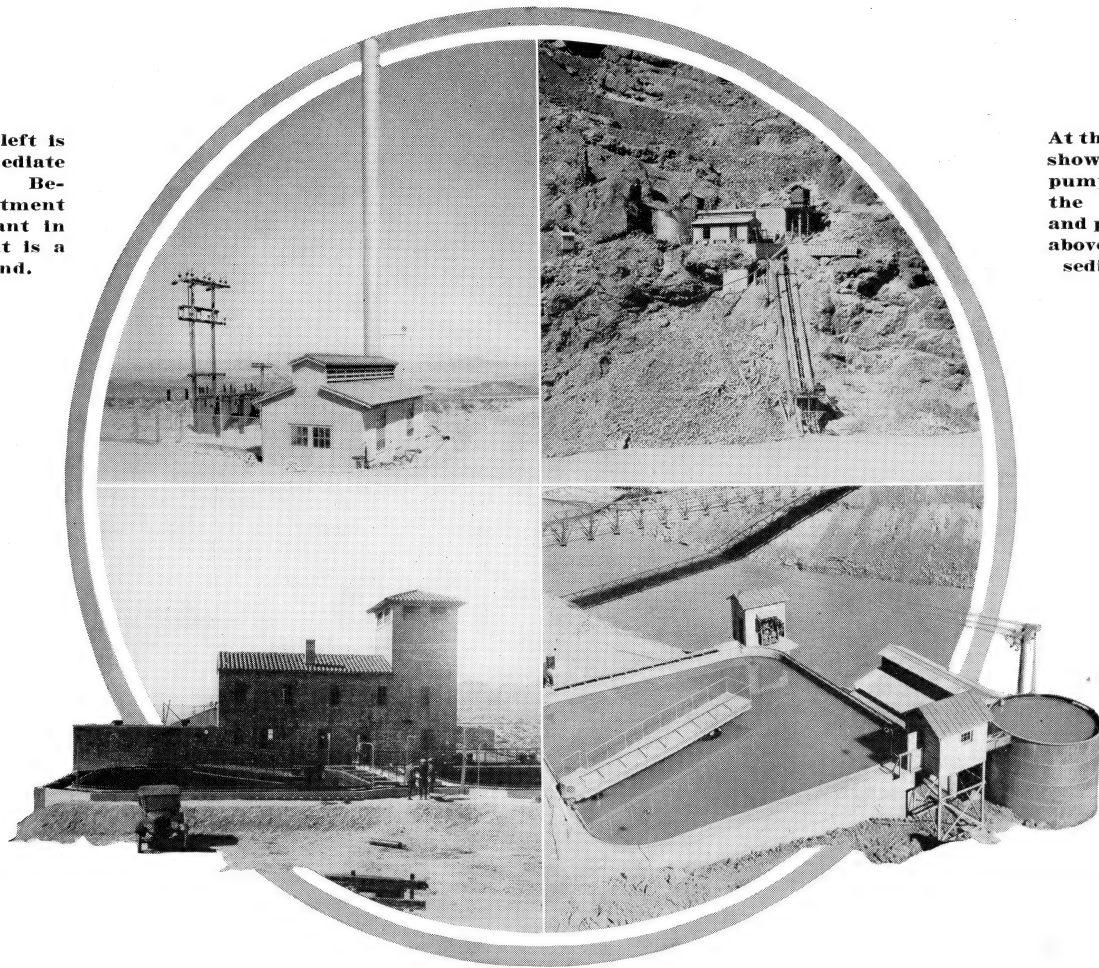
Two lifts or stages of pumping are required to raise the water from the clarifier to the treatment plant at Boulder City. The pumping equipment at both stations consists of three 4-stage, 450-gallon-per-minute, 1,200-foot-head centrifugal pumps. The lower units force the water through 20,000 feet of 10- and 12-inch steel pipe to a booster station almost 1,100 feet higher. The second bank of pumps, which takes its supply from a surge tank 90 feet high, pushes the water through 14,500 feet of pipe and raises it 850 feet to a 100,000-gallon tank in Boulder City. Extensive treatment and filtration equipment is installed there to soften the water and further to clarify it. Following filtration, the water is chlorinated and pumped to a 2,000,000-gallon storage tank on a high knoll just north of the town. Three 500-gallon-per-minute, 170-foot-head pumps serve to give it this final lift of 150 feet. All pipe in the system is buried approximately 3 feet deep.

The system was designed by Burton Lowther, of Denver, consulting hydraulic and sanitary engineer to the Bureau of Reclamation. It was built under a number of contracts covering its various phases.

River water, untreated except for pre-sedimentation and chlorination, was delivered to the storage tank for the first time on September 9, 1931, thereby providing an emergency supply for the city. Up to that date, Six Companies Incorporated had been hauling water in tank cars from Las



Top view at the left is of the intermediate pumping station. Below is the treatment and filtration plant in Boulder City that is a model of its kind.



At the right the top view shows the movable pumps at the river and the pre-sedimentation and pumping structures above. Below is the pre-sedimentation basin.

Essential structures in the Boulder City water-supply system.

Vegas. The daily consumption during the torrid summer months was as much as 50,000 gallons, and cost from half a cent to three-quarters of a cent a gallon. The city distribution pipes and the treatment plant were not installed until months later, so that the water system was not functioning in its completed form until February, 1932. A sewage-disposal plant is being constructed about a quarter of a mile from the city limits.

An area of 110 square miles, of which Boulder City is a part, was withdrawn from public entry in 1921 and, except for a few pieces of patented ground, is entirely under Government control. While never formally declared a reservation by Congress, it was established under Nevada statutes. Visitors approaching Boulder City must halt at a sentry station, and passes must be procured before proceeding further. Contractors' workmen are hired in Las Vegas and given credentials to admit them to the reservation. Sight-seers bent upon having a look at the construction drama in the canyon are shown every courtesy, but they are not allowed in the working zone. The nearest vantage point for them is Lookout Point, a rocky crag nearly 800 feet directly above the dam site on the Nevada side, where a place of observation has been established.

The Government intends to retain jurisdiction over all the land in Boulder City during the construction period in order that it

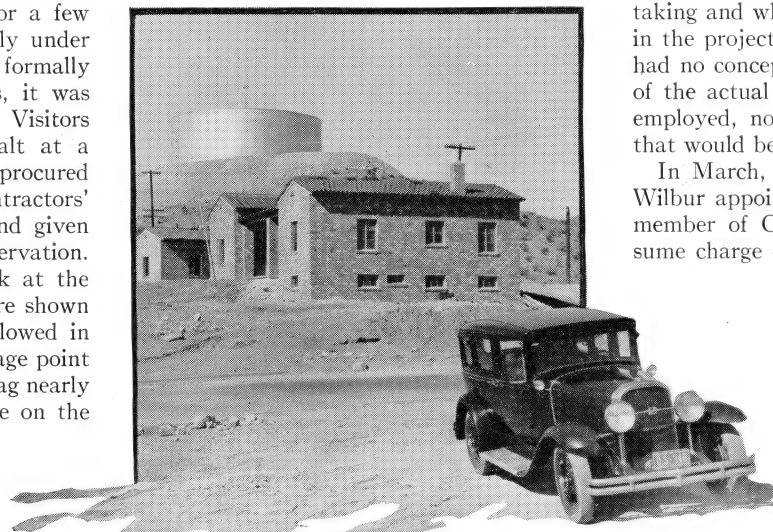
may have full control of activities there. No business or professional enterprise can be established in the town except under Government permit. Land for business or residential purposes cannot be bought, it can only be leased; and structures built thereon must be approved from the plans before construction can start. Leases run for a maximum of ten years, being limited because of the uncertainty of Boulder City's status after the dam is completed. The future disposition of such leases

will be determined upon their expiration. They may be extended, or the land may be sold.

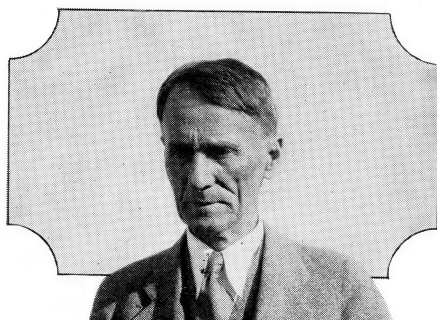
Establishment of these stringent regulations was deemed advisable to prevent a wholesale influx of people, with consequent unemployment, ruinous business competition, and widespread infractions of laws. Even before the dam contract had been awarded, the Bureau of Reclamation was deluged with inquiries from persons in all parts of the country who had read of the great undertaking and who desired to engage in business in the projected town. Most of these people had no conception of the climatic conditions, of the actual number of men that would be employed, nor of the business opportunities that would be available.

In March, 1931, Secretary of the Interior Wilbur appointed Louis C. Cramton, former member of Congress from Michigan, to assume charge of the appraisement of lands in

Boulder City and of the making of lease concessions. Mr. Cramton formulated regulations governing the granting of permits for conducting business and for leasing ground, and these he published in a pamphlet together with a general description of conditions that would be met with in the construction town. This information was issued



Some Government residences and, above them, the 2,000,000-gallon water-distribution tank on a hill above Boulder City.



Sims Ely, city manager of Boulder City.



on May 18, by which time more than 3,000 letters of inquiry had been received and placed on file by Jesse W. Myer, chief of the mail and files section of the Bureau of Reclamation, who had been detailed to Las Vegas to classify them for handling. Additional mail inquiries were coming in at the rate of fifteen a day, and as many more persons were calling at the Las Vegas office. It having been decided that only formal requests for permits would be considered, a pamphlet and an application blank were sent to each inquirer. A \$10 fee to show good faith was required with each application, the sum to be returned if no permit were granted. The informal inquiries continued in volume and totaled more than 4,000 up to October 1, 1931, but on that date only 320 persons had returned the official blanks accompanied by the fee.

The system adopted effectively curbed a mushroom growth and undoubtedly averted confusion, disappointments, and hardships. Said Mr. Cramton at the time the regulations were drawn: "There is no doubt that, if the Government desired, it could create in Boulder City in the next year one of the most spectacular boom towns in recent history. If we were to reply to inquirers without discouragement and without limitations, simply setting aside the necessary lots for business and residential purposes, I have no doubt a thousand or more persons would sell out what they have at home and go to Boulder City expecting to make their fortunes there. Ruin would inevitably follow any such movement, for the business possibilities are limited. Certainly the Bureau of Reclamation does not desire to have any part in such wholesale business disaster."

Formal applications for business permits were received from persons in 36 states and covered more than 60 types of business, ranging in alphabetical order from automobile sales to welding. Had all who applied set up establishments, there would have been in Boulder City 31 drug stores, 21 indoor recreation rooms, 16 barber shops and beauty parlors, 14 restaurants, 14 filling stations, 12 soft-drink shops, and innumerable stores of other kinds. To guard against such over-commercialization, the Government set up four classifications to guide the granting of permits:

1. Exclusive—Public utilities and similar operations. Only one permit for each classification.

2. Limited—Mercantile stores, such as groceries and markets. At least two competing permits in each line.

3. Special—Banks, motor lines to outside points, etc. The number of permits to be governed by the prevailing conditions.

4. Personal—Professional services such as doctors, lawyers, and dentists. Permits to be granted subject to authorization in the states where the respective applicants reside.

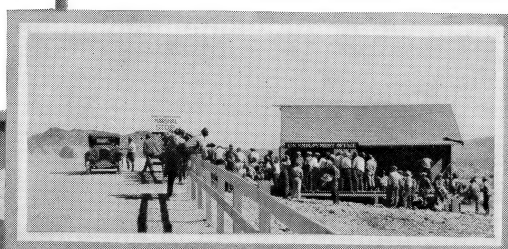
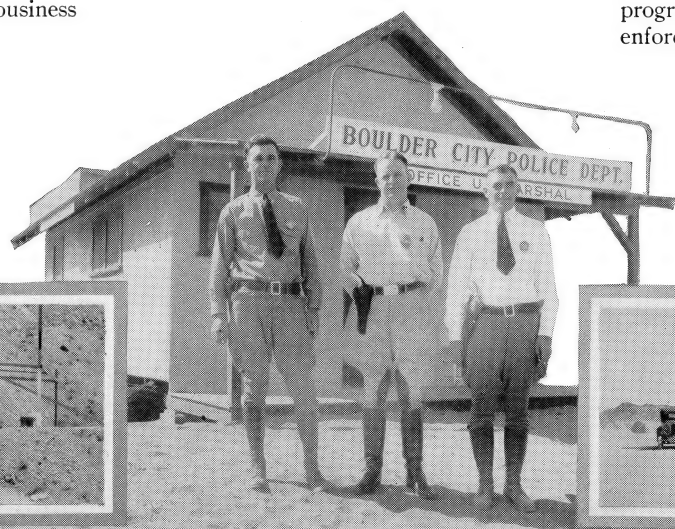
The field for business enterprises is narrowed through the fact that Six Companies Incorpo-

rated maintain various retail establishments essential to the needs of their employees, including a dining hall, department store, recreation hall, laundry, and barber shop. A business permit carries with it the right to lease ground for business purposes. The average annual rental for a business lot 40x120 feet is \$275. Any person of good character may lease ground for residential uses at an average annual rental of \$120 for a lot having a 50-foot frontage.

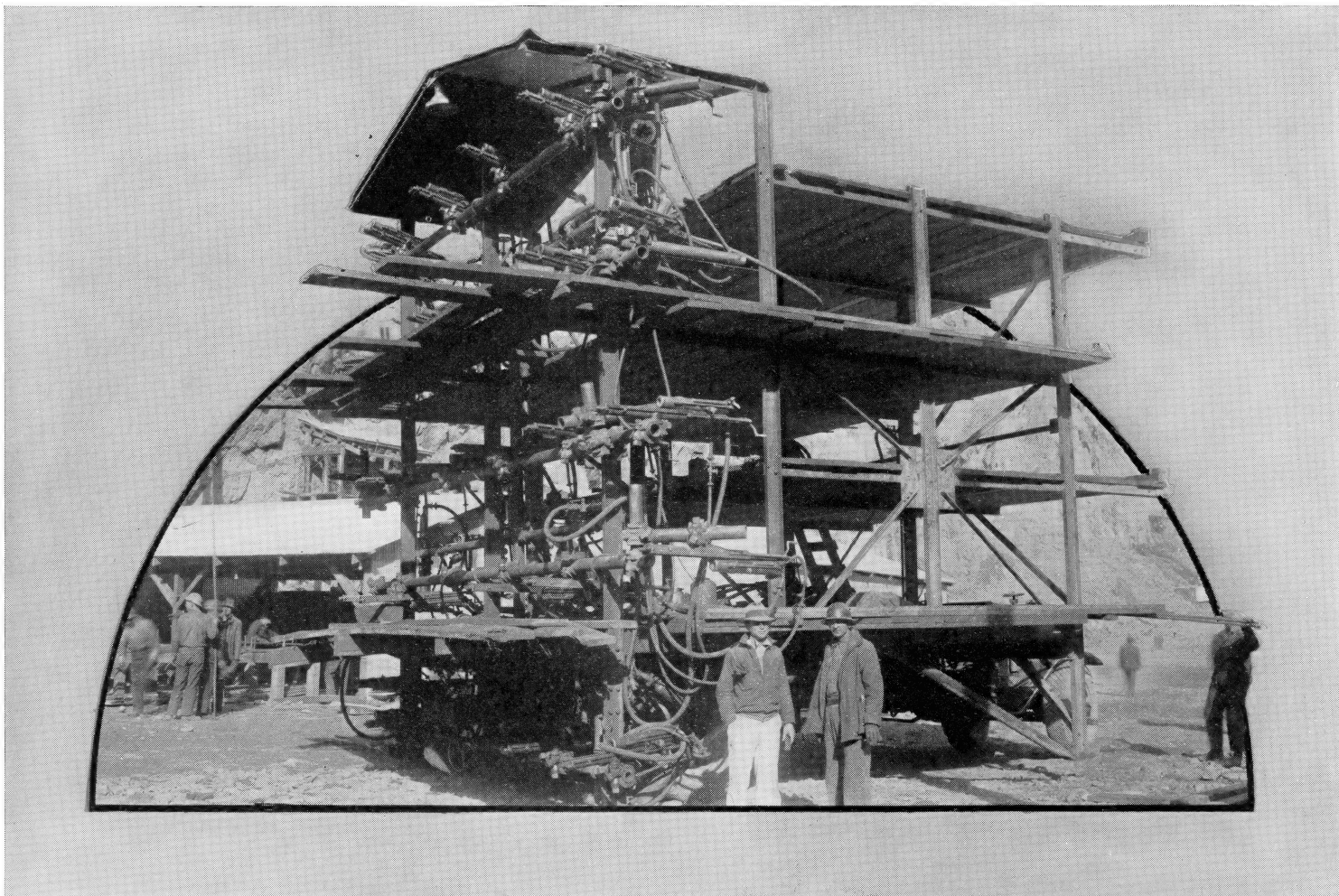
Up to March 1 of this year 114 business permits had actually been granted, and 26 retail and wholesale establishments had been set up. Buildings erected or in course of erection for these purposes totaled eighteen. Twelve permits to lease residential lots had been issued, and two homes had been built or were under construction.

Sims Ely, of Arizona, heads the administrative staff of Boulder City as city manager. He was appointed by Secretary Wilbur and reports to Walker R. Young, construction engineer in charge of the project for the Bureau of Reclamation. He is assisted in governing the town by an advisory board of three men, of whom two represent the Government and one represents the contractors.

The policing of Boulder City, as well as of the entire reservation in which it is located, is in the hands of deputy United States Marshals. A force of nine men is headed by a chief ranger. G. E. Bodell is chief of police of Boulder City. Laws prohibiting gambling, the sale of liquor and narcotics, and other practices which the Government deems injurious to the workers and to the orderly progress of the work in the canyon are rigidly enforced.



Left—The first office of the United States Marshal. Center—Chief of Police Bodell of Boulder City flanked by two members of his force. Right—The gateway to the reservation where all visitors must secure passes.



One of the drill carriages, with drills in place, shown outside a tunnel portal. The man at the right, in the foreground, is wearing a metal hat of the type adopted for the protection of workmen who are exposed to the hazards of falling rocks.

Mammoth Drill Carriages Speed Hoover Dam Tunnel Work

ALLEN S. PARK

THE accompanying illustrations show the rock-drill carriage which is materially aiding Six Companies Incorporated in driving the huge tunnels that will carry the Colorado River through the solid rock walls of Black Canyon while the Hoover Dam is being built.

This type of carriage, which is believed to be the largest ever constructed, makes it possible to mass 24 to 30 Ingersoll-Rand N-75 drifter drills in a simultaneous attack against the tunnel breast, and is perhaps the most important factor in enabling the contractors to carry on tunneling operations at a much faster rate than was thought possible prior to the beginning of the work.

The carriage or jumbo, as it is familiarly known on the job, is the creation of Bernard Williams, general foreman of work in the canyon. He designed and directed construction of the first unit, which proved so effective that similar devices were built and adopted for all the enlargement work.

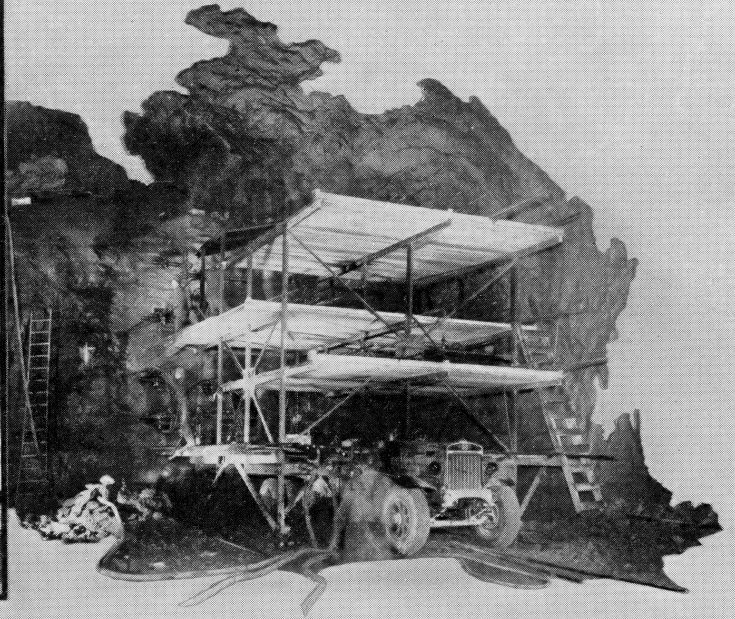
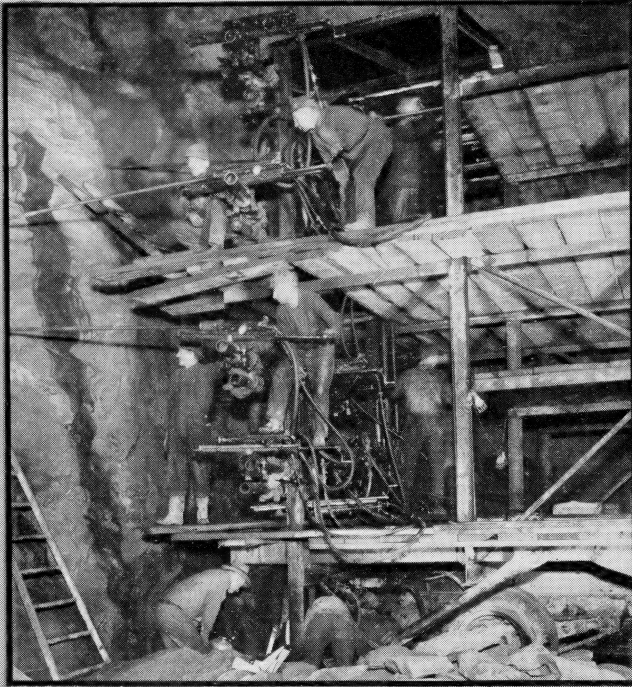
Each of the four diversion tunnels will be 56 feet in diameter and approximately 4,000 feet long. Considering their length, they are of record size. The Rove Tunnel in France, completed by the French Government in 1927, is 78 feet 6 inches wide and 54 feet 4 inches high, but of short length. No other bore through rock has ever equaled the overall proportions of the Hoover Dam tunnels.

It is obvious that the advancement of such enormous faces presented perplexing problems. The operations required are on such a vast scale as to almost fall in the category of quarrying rather than of tunneling. Six Companies Incorporated considered many possible systems of procedure before beginning actual work. The plan suggested by Mr. Williams was the first one tried; and its success saved much time and money which might otherwise have been expended in experimentation.

The general plan of tunnel advancement was to drive 12x12-foot pioneer headings at the top of the cross section of the 56-foot area

ultimately to be taken out. Enlargement was started, however, long before these smaller headings had been completed. In fact, the drill carriage was first tried out at the lower portal of Tunnel No. 4, where the pioneer tunnel had not yet been started. Even there, though, a heading 12 feet high and extending to the arch lines of the completed size was kept one round in advance of the bench. Thus, the procedure was essentially the same as though the pioneer bore had already been driven. As they are now being excavated, the enlargements are carried to their full width but only 40 feet high. This leaves 16 feet in the bottom or invert to be taken out later. With a 12-foot heading excavated at the top, there remains a bench 30 feet high, 56 feet across at its widest line, and 50 feet in average width.

"We wanted some method of driving the tunnels without using ring drilling and without putting in down holes," said Mr. Williams in discussing how they approached the prob-



Two views of a "jumbo" at a tunnel heading. At left, drillers are pointing their machines preparatory to starting a round. The other picture shows a carriage, mounted on its 5-ton truck, backed into position for drilling one side of the 56x30-foot bench.

lem of developing the drill carriages. "Since we had to carry the tunnels at least 40 feet high to allow working headroom for the Marion Type 490 electric shovels to be used in excavating, a 12-foot heading and a 30-foot bench were determined upon as the best plan of attack. A method then had to be devised to drill flat holes in the bench. A drill carriage of some sort seemed to offer the greatest possibilities of filling the requirements. As we intended mucking into trucks, a truck-mounted carriage was the logical solution. It was essential that the drill carriage and the shovel be able to pass in the tunnel, so we decided upon a carriage wide enough to drill half the bench at one set-up."

As can be seen in the pictures, the drill carriage has a steel skeleton which supports wood platforms at four levels. Two of these platforms extend the full length of the carriage and provide working stations for the drilling crews. The other two platforms are of shorter length and serve as drill-steel racks. They are partitioned so that each machine has its set of steel always handy.

The drills are supported on transverse pipe bars secured to the outside of the frame uprights at five levels. Extension arms at the ends of these bars permit of setting up drills for driving holes at suitable angles into the side walls to break the rock approximately to the curve line of the finished excavation

desired. Four of the five lines of drills are operated from the two platforms, and the lowest one is operated from the ground.

The carriage is piped for air and water immediately below the drills. A 6-inch air pipe and a 2-inch water pipe are run along the floor of the tunnel at one side up to within 100 feet of the bench. These services are extended to the carriage through the medium of three 2-inch hose lines, two of them for air and one for water. The lines connecting the drills with these sources of supply are 5 feet long. Thus each machine can be moved laterally 4 feet either way from its central position, which is ample to meet all drilling conditions. An apron of sheet steel built above the drills protects the operators from falling rock. The steel uprights of the frame at the four corners of the carriage reach nearly to the ground. This permits blocking the carriage solidly in drilling position with screw jacks. As a result, vibration has never proved bothersome, even with 24 drills running.

To set up the carriage for work it is necessary only to back the truck into position, connect the water and air lines, block up the corner posts, and point the machines. The average time required for these operations is twenty minutes, but they have been performed in as few as ten minutes.

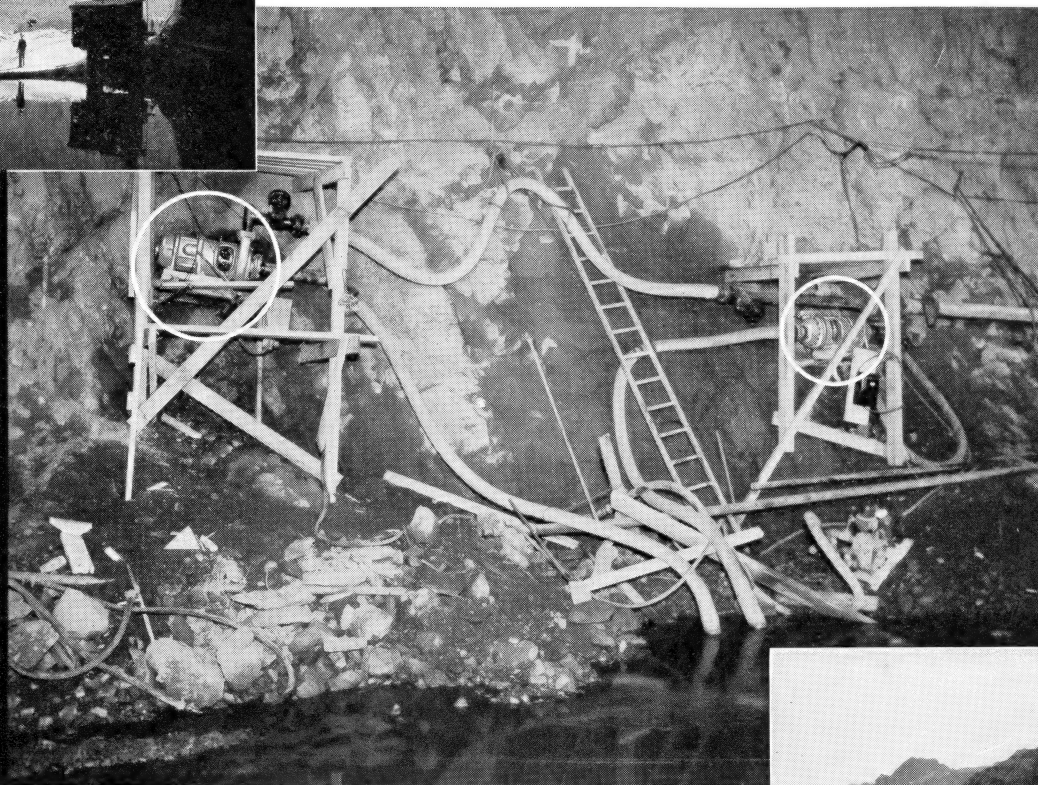
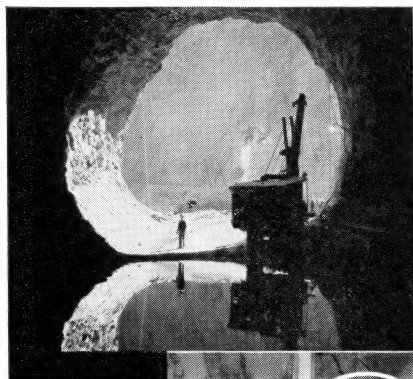
After half of the bench has been drilled from one setting of the carriage, the truck is

pulled away and backed into position for drilling the other side. When this second half has been drilled, the truck is moved out of the danger zone and the entire round is blasted at one time. After the blast the power shovel is brought up to the face to load the muck into trucks. With the operations thus systematized, there is a minimum loss of time. Records kept for one week at the beginning of the enlargement work in all the tunnels show that the average drilling time was 4.38 hours, the average mucking time 6.95 hours, and slack time only 2.96 hours. Thus the total average time required for a complete round was 14.29 hours. The average advance for each round was 15.11 feet. These figures were considerably improved upon as the crews became better trained; and before the first tunnel was holed through the average advance per round was not only increased but at some faces three rounds were completed in 24 hours.

The success of the drill carriage on the enlargement work has prompted the engineers for Six Companies Incorporated to modify it and to use it for drilling the remaining bottom section of the large tunnels. Detailed information on this work is not yet available; but it is the consensus of opinion that the drill jumbo can be utilized to very good advantage.

MOTORPUMPS Handle A Tough Job

On The Hoover Dam



Two Cameron MOTORPUMPS mounted on drill steels in the walls of one of the Hoover Dam diversion tunnels.

THE two Cameron MOTORPUMPS above remove seepage water from one of the huge diversion tunnels at Hoover Dam. This water is like thick soup in consistency and is constantly being stirred up by the passage of trucks through the tunnel.

After being on the job 24 hours a day for three months the pumps were opened for inspection and found to be only slightly worn despite the abrasive character of the water.

The contractors, Six Companies Inc., are using 15 MOTORPUMPS for various services on this job. The ease with which they may be moved about and their ability to operate in any position without special mounting make them ideal for such service.

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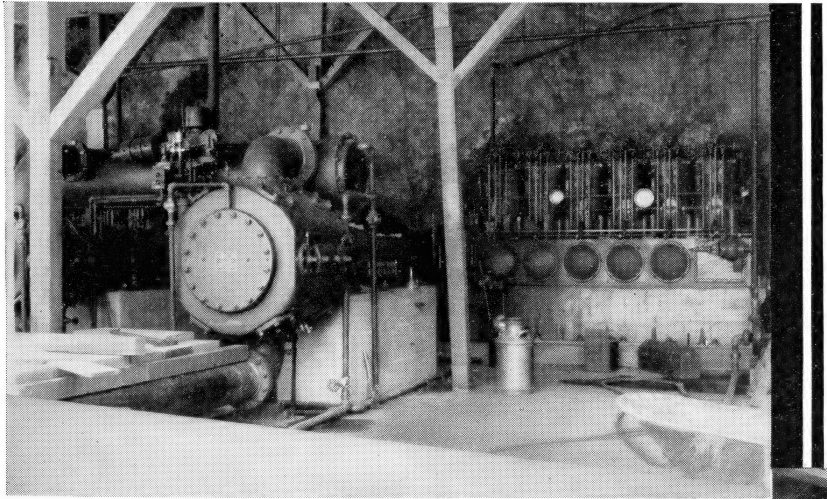
Ingersoll-Rand

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The Colorado river at the lower end of the Hoover Dam diversion tunnels.

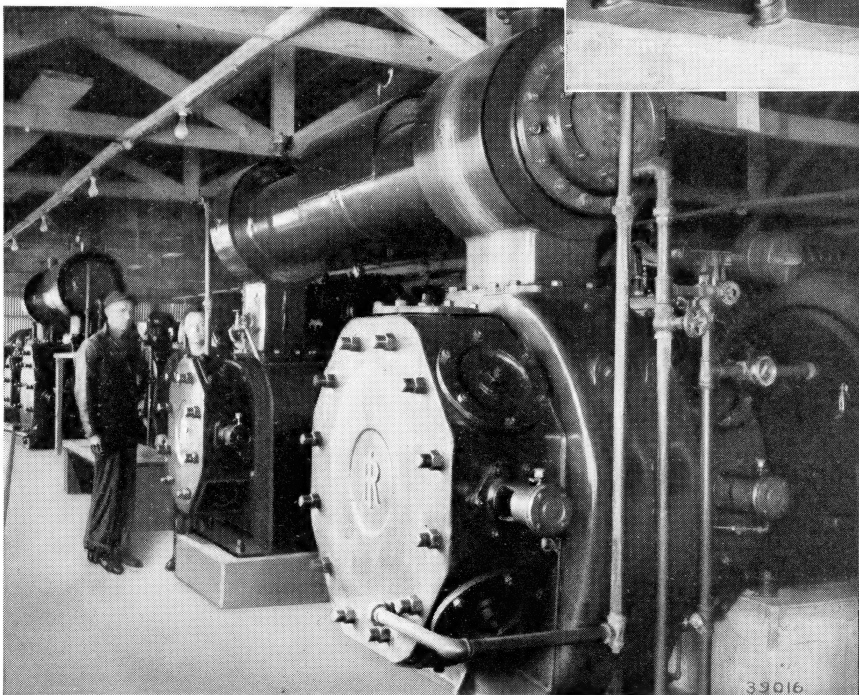
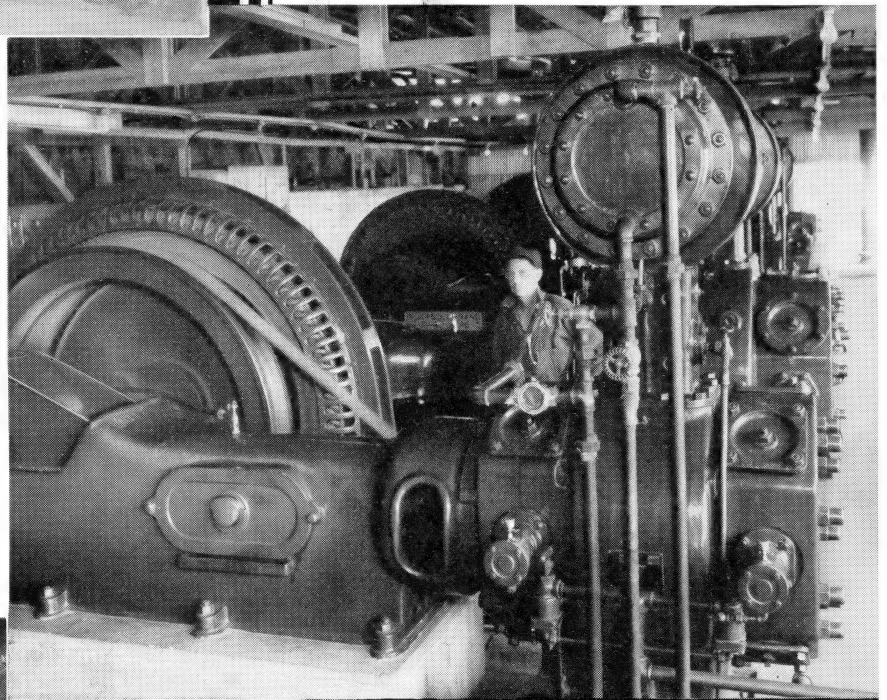
I-R Compressors Run 24 Hours



All pneumatic equipment used on the Hoover Dam project by Six Companies Inc. was supplied by Ingersoll-Rand.

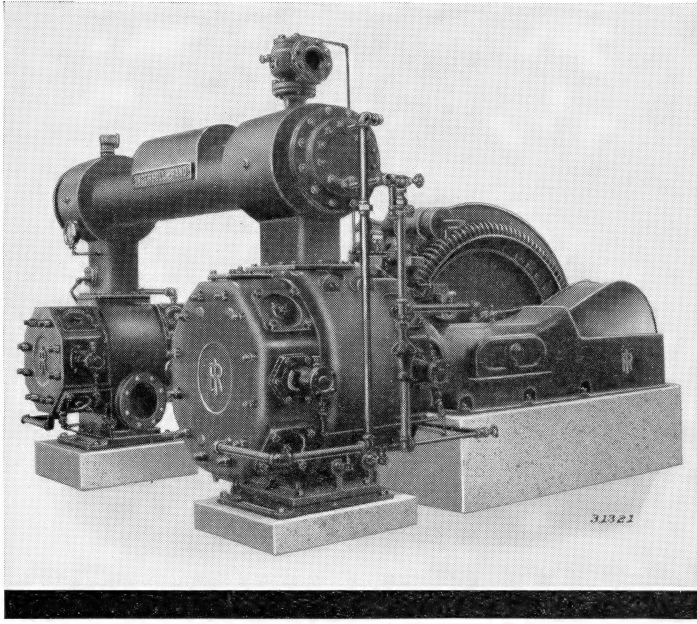


Above is one of the first Ingersoll-Rand Compressors to be put in operation. At the time this photo was taken the compressor was being driven by a diesel engine which was used until electric power became available.

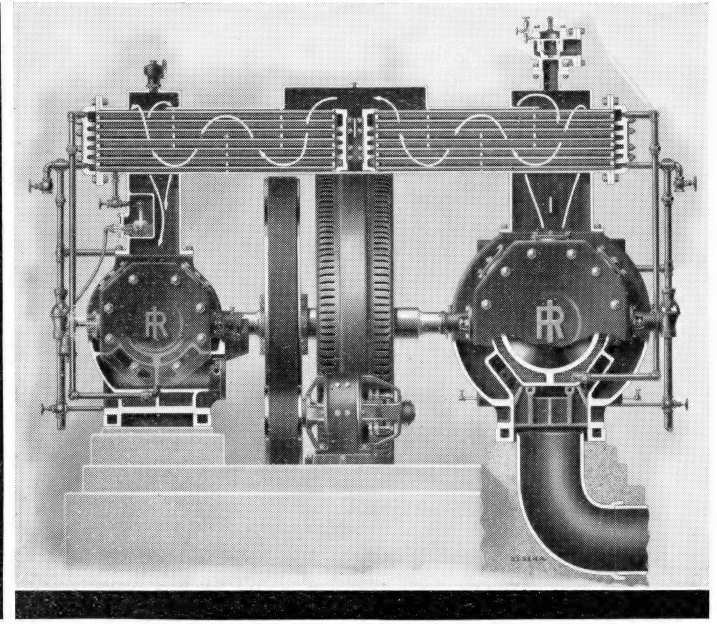


Above and at the left are two views of the compressors in Plant No. 3—the largest of three compressor stations.

Every Day at the Hoover Dam



*I-R Direct-Connected, Electric-Motor-Driven Air Compressor.
Eleven such compressors are at work on the Hoover Dam.*



*Head end view of compressor showing arrangement of cylinders,
intercooler construction, and motor on compressor shaft*

FOR approximately a year while tunnel drilling at the Hoover Dam was at its peak, Ingersoll-Rand Compressors operated 24 hours a day, seven days a week. This service was maintained weeks at a time without a shut-down. There were close to 500 air-driven machines dependent on these compressors.

On this stupendous job, there are eleven I-R electrically-driven air compressors having a total capacity of 19,000 cu. ft. piston displacement per minute. All but two are served by I-R tubular-type air aftercoolers. These coolers add to the efficiency of the drills by eliminating troubles arising from moisture in the air lines.

Each compressor is equipped with the I-R patented 5-step Clearance Control. This method of control is recognized as the most efficient and reliable method ever devised for regulating the air output of a constant-speed compressor. It maintains constant pressure at the compressor discharge by automatically regulating the clearance in the compressor cylinders to agree with the amount of compressed air being used. This feature along with others of like importance is only obtainable in I-R Compressors.

Six Companies Inc. chose I-R compressor equipment because they knew they could count on its efficiency and reliability.

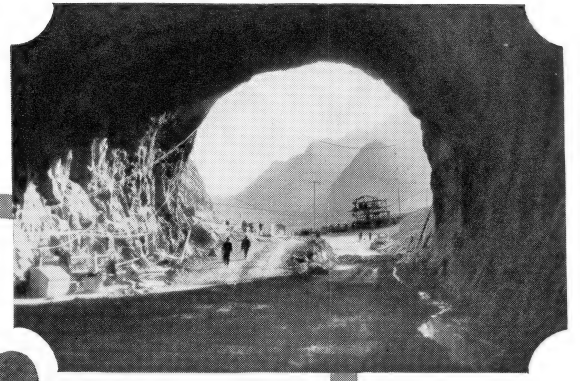
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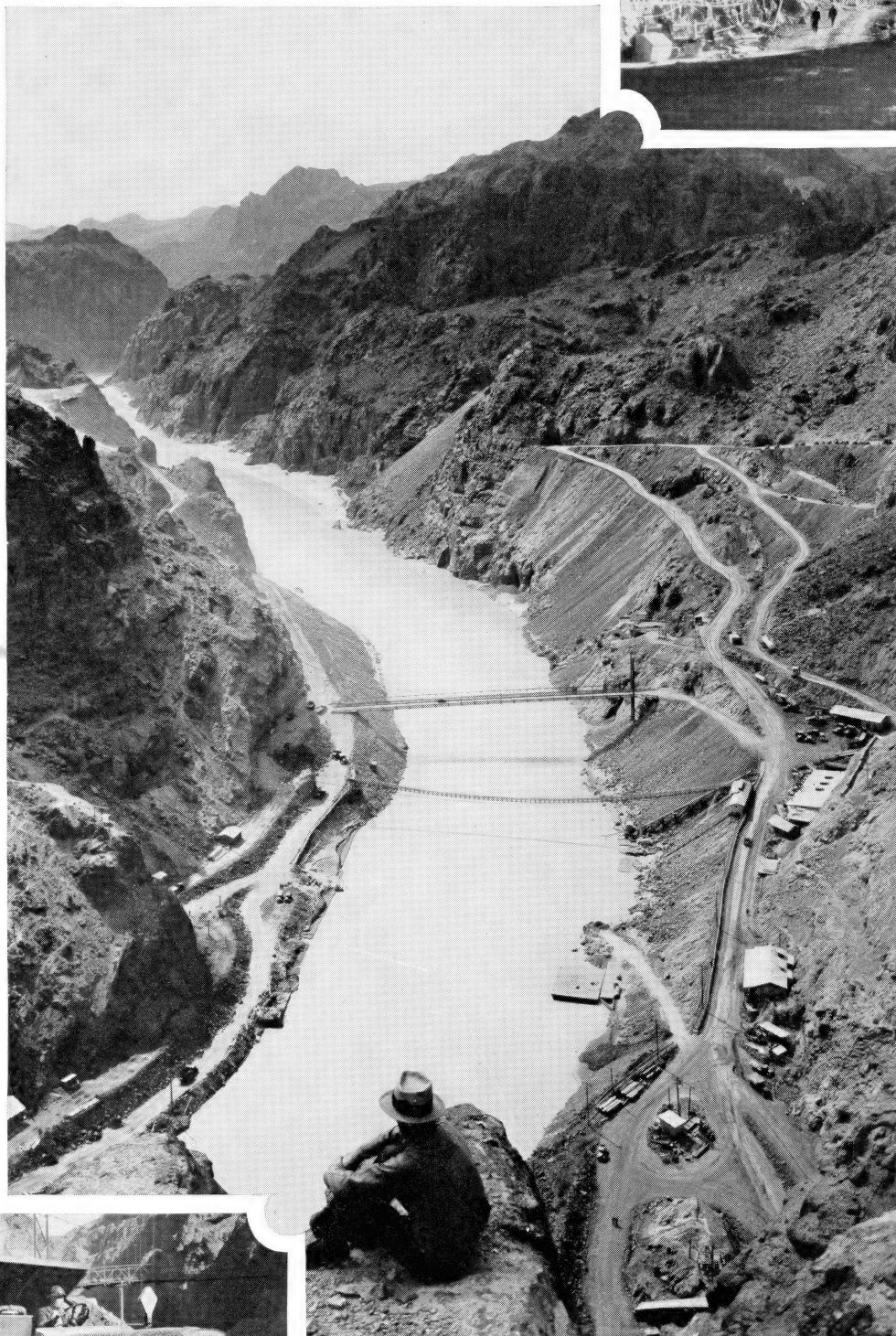
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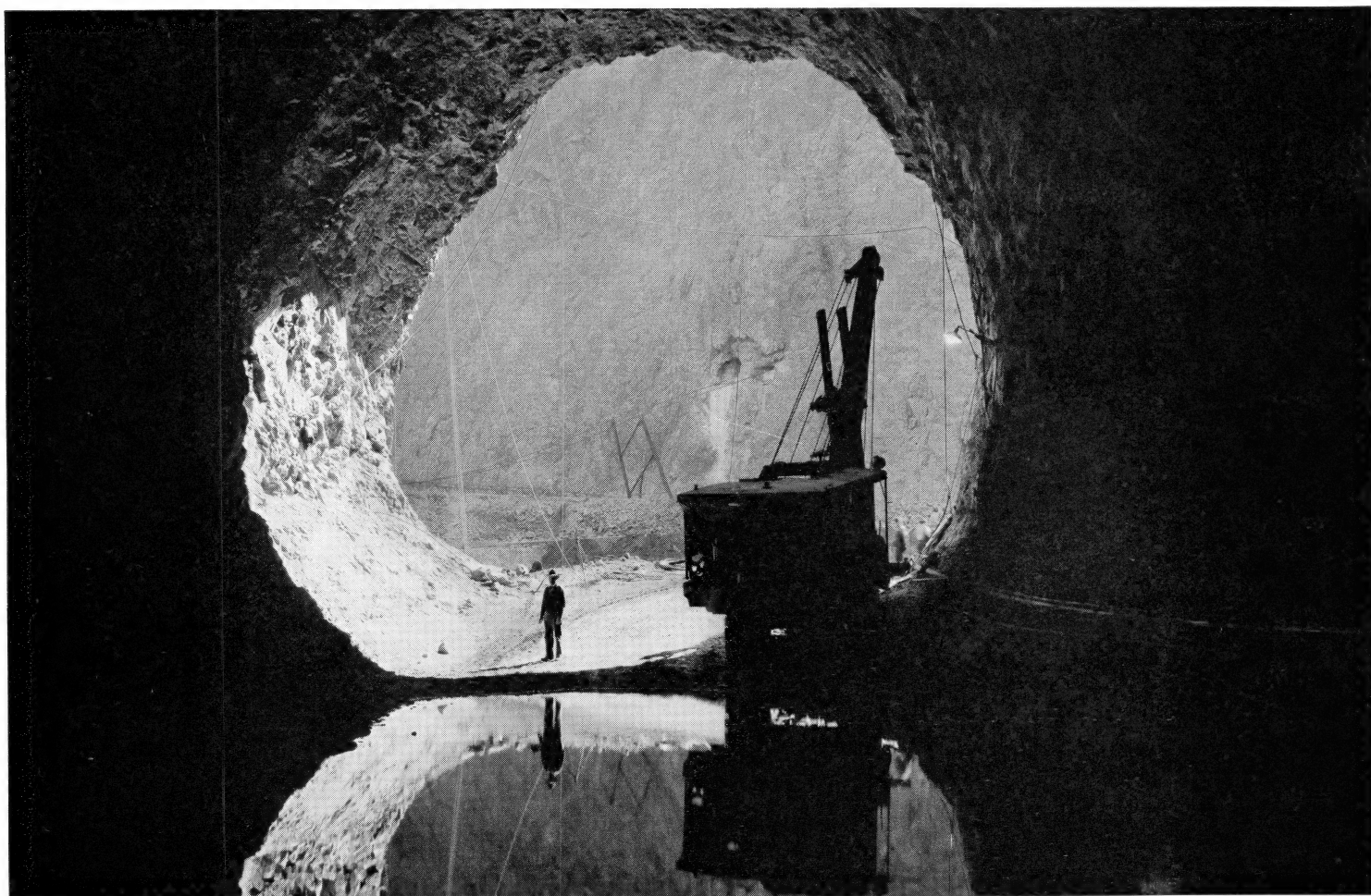
Human beings be-
come pygmies in
such a setting.



Muck truck with
protective hood
over the driver.



Lower end of the workings and the network
of roads for disposal of the tunnel spoils.



Looking out of the gaping maw of one of the huge diversion tunnels.

Construction of the Hoover Dam

Details of the Driving of the Four Huge Tunnels which will Divert the Colorado River Around the Dam Site

NORMAN S. GALLISON*

THE first major operation confronting Six Companies Incorporated in the building of the Hoover Dam was the driving of four great tunnels through solid rock. These will carry the Colorado River around the dam site while excavation for the dam foundation is underway, and thereafter until the massive concrete barrier has been partially erected. There are two of these diversion bores on each side of the river. As driven, they are circular in cross section and 56 feet in diameter. After being lined with 3 feet of concrete, they will have a finished section of 50 feet. Their combined length is 15,909 feet, and their individual lengths are: No. 1—4,300 feet; No. 2—3,879 feet; No. 3—3,560 feet; and No. 4—4,170 feet.

At the dam site, the river flows through a narrow box canyon whose walls rise sheer from the water's edge to a height of 800 to 1,000 feet. The tunnels enter these precipitous cliffs about 2,000 feet upstream from the

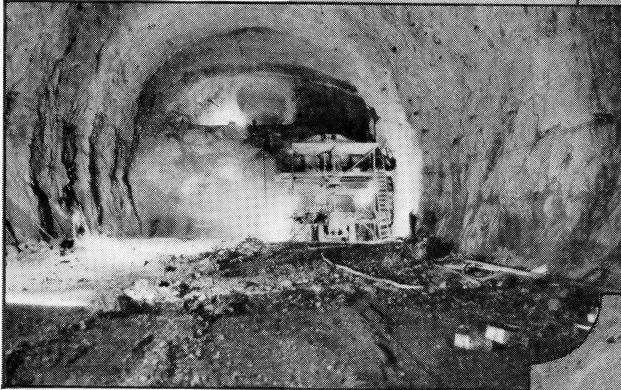
axis of the dam site, follow roughly semi-circular courses through the walls, and emerge approximately 2,000 feet downstream from the dam site. The beds of these passageways are a few feet lower than the normal river level. From intake to outlet, each bore has a fall of about 14 feet. The intake portals of the two tunnels on each side of the river are relatively close together but, owing to the conformation of the canyon walls, they are not truly parallel and are farther apart at their outlets.

After these tunnels have served their primary purpose of diverting the river's flow, they will not be abandoned. The two nearer the river will be closed off with concrete plugs, above and below the dam. In the lower plugs will be installed needle valves, which will serve, through the penstock pipes, as outlets for regulating the flow of the river below the dam while the reservoir is filling to the elevation of the intake towers. These tunnels will also house the pressure penstocks from the intake towers for a portion of their

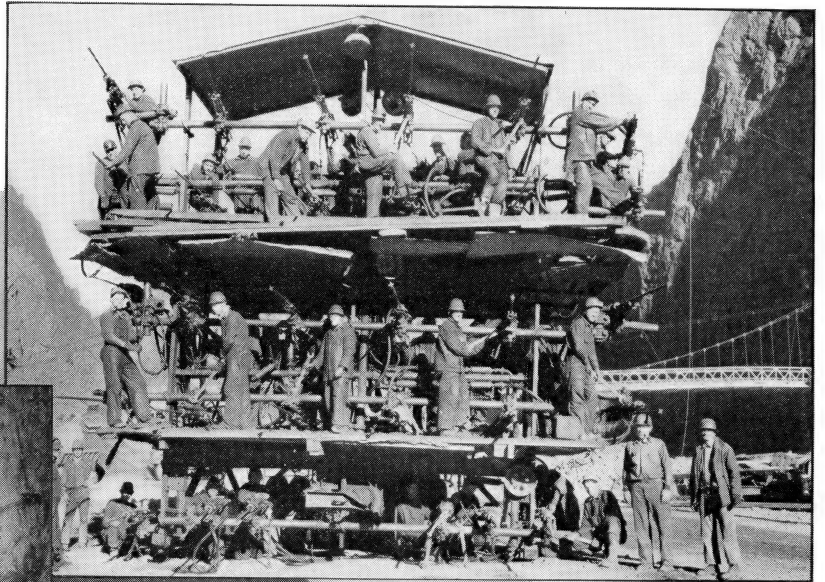
length. The outside set of tunnels will be bulkheaded at the upper portals and about midway in their courses, from which latter points steeply inclined tunnels driven to the surface will, when equipped with suitable structures at their tops, act as spillways for the overflow waters.

The driving of the four tunnels involves the excavating of nearly 1,500,000 cubic yards of rock within the tunnel lines. A further vast amount of material was removed in gaining access to the various points of work. Operations were started in May, 1931, and at the present time it seems reasonably certain that they will be completed during the present month, so that the total elapsed time required will have been about a year. This is considerably under the best estimates made prior to the beginning of work. Operations have been carried on 24 hours a day, in three 8-hour shifts. As many as 1,500 men have been engaged in the tunneling activities, and the average number employed has been 1,200.

*Public and Press Relations Division, Six Companies Incorporated.



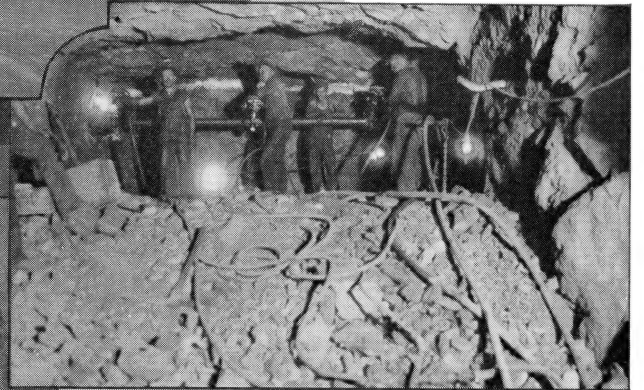
Above—Drill carriage at work in tunnel.



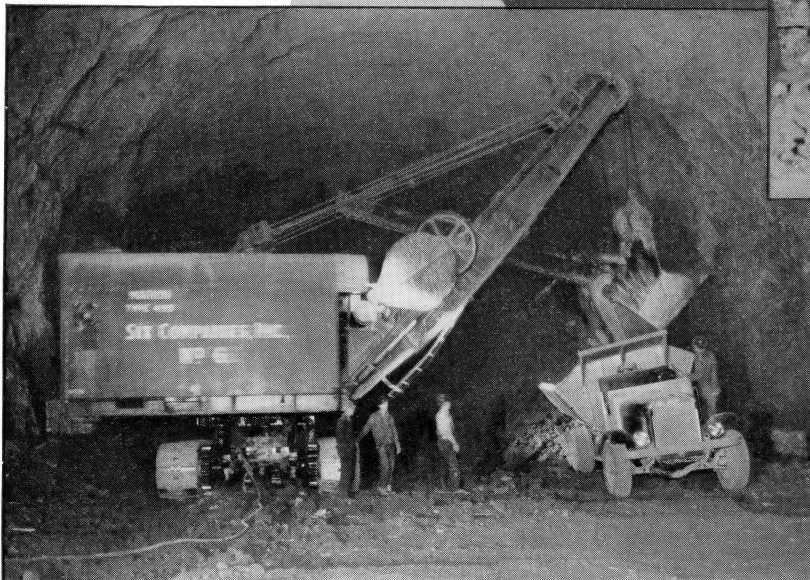
Above—Bench drill carriage and full crew.



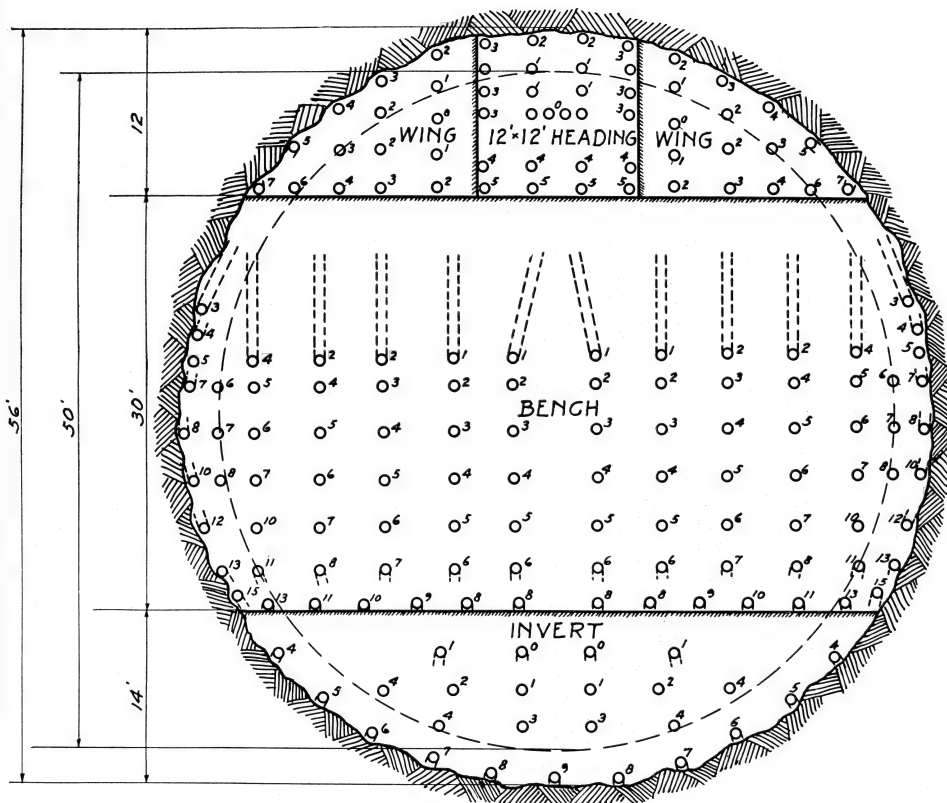
Right — Lower tunnel portals during flash flood.



Drilling crew in 12x12 top heading.



The boom swings and 3½ cubic yards of muck is loaded.



Holes were located as shown above and fired in the various sections in the order indicated.

As soon as they took hold of their contract, Six Companies made preparations to begin tunnel driving, with the result that drills were biting away at the rock several weeks before a roadway had been constructed into the bottom of the canyon. About two miles above the dam site, the canyon broadens out into the reservoir area. There, at the foot of Hemenway Wash, access to the river level by trucks could be had over a rough desert road. Barges were constructed at this point; Ingersoll-Rand Type 20 and Type XL portable air compressors and drilling tools were loaded aboard; and the first expedition set forth. The only spot in the canyon proper where a foothold could be obtained was on the Arizona side of the river, near the center of the future dam. At this point was a small talus slope formed by rocks which had fallen from the cliffs above. Workmen on the barge, which was lowered downstream by cable, were able to moor their craft and unload compressors, a portable blacksmith shop, drills, and other equipment among the rocks.

The plan of attack adopted by Six Companies Incorporated was to drive adits into the canyon walls on either side of the river to intersect the lines of the diversion tunnels midway between portals. The first hole was drilled for the Arizona adit on May 12, 1931. Ingersoll-Rand Type N-75 drifter drills and Type S-49 "Jackhammers" were used. The muck was hand shoveled into 1-cubic-yard mine dump cars and deposited along the canyon wall to enlarge the bench for further buildings. A cable suspension footbridge was then thrown across the river to gain access to the Nevada side. There a shelf was blasted from the cliff, and operations were begun in the same manner as on the opposite shore.

These adits were driven 10x8 feet in cross section. The Arizona entry was 850 feet long, and that on the Nevada side 630 feet long.

Electric power was available on June 25, 1931. Prior to that time two Ingersoll-Rand Type XRE stationary compressors, each with a 1,302-cubic-foot piston displacement, were installed and connected to two 200-hp. Atlas diesel engines. These units furnished air for driving railroad tunnels and for roadbuilding. When power lines had been strung, the machines were converted to electric drive. About the same time a compressor plant near the Arizona adit was placed in operation, and this supplied air at 105 pounds pressure through 4-inch lines to the adit drilling crews. The plant consisted of two Ingersoll-Rand Class PRE units, each of 2,195 cubic feet per minute piston displacement. Later another compressor station was established near the lower portals of the tunnels on the Nevada side. It contained four Type XRE and two Class PRE machines having a combined piston displacement of 9,598 cubic feet per minute. All three of these compressor plants were interconnected by 6-inch lines; and air was distributed to the various points of use through a system of 4- and 6-inch mains having an aggregate length of some 30,000 linear feet.

Ten-ton Baldwin-Westinghouse storage-battery locomotives and 3½-cubic-yard West-

ern dump cars were brought in by barge and used to haul muck. When the lines of the diversion tunnels were reached, 12x12-foot top headings were opened off the adits in both directions. The purpose of driving the top headings in the main bores was twofold: to provide ventilation and convenient access for the enlarging operations which were to follow, and to furnish accurate information as to the character of the rock to be encountered throughout the length of the tunnels. By driving the adits, eight faces were opened up for attack in addition to those at the portals. Actually, the bulk of the footage in the top headings was driven through the adits. As soon as access could be had by cutting a road down the steep canyon walls, top headings were opened up at the lower portals of the two tunnels nearer the river and driven upstream toward the adits.

When electric power became available, top headings were drilled from a rig consisting of two horizontal bars or vertical columns mounted on a drill carriage running on the narrow-gauge rails used for mucking. Thirty-two holes, 10 feet deep, were drilled to a round, and the average depth broken per round was 8.3 feet. Mucking was done by Conway mucking machines. Crews working from the adits alternated as to headings, drilling one face while mucking operations were underway at the other. Although sixteen possible faces were available, actual conditions prevailing on the job were such that twelve faces was the most ever worked at one time. Progress in the top headings by months was as follows:

June.....	410 ft.	October.....	4,147 ft.
July.....	1,045 ft.	November...	3,025 ft.
August.....	1,439 ft.	December...	1,191 ft.
September...	3,235 ft.	January.....	120 ft.

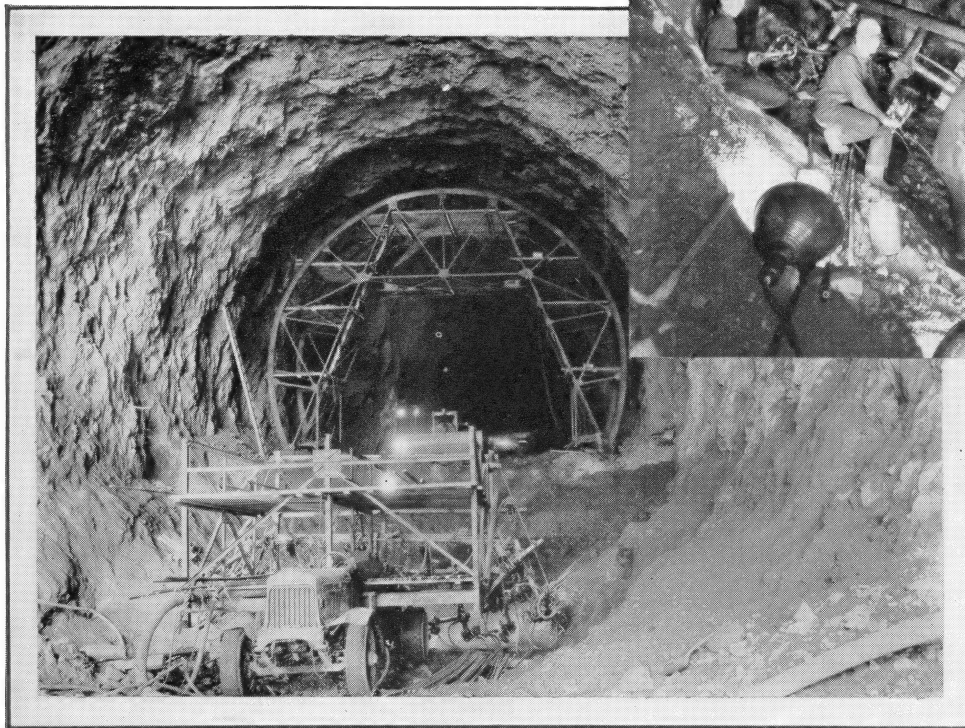
It will be noted that the total of 14,612 feet does not correspond with the combined length of the diversion tunnels. This discrepancy is due to the fact that the main bench operations were started on several of the portals before the top headings were completely driven through from the adits. Rock excavated from the top headings totaled 79,000 cubic yards. Much of this muck was dumped along the canyon walls to form roadways from the adits to the lower portals.

In gaining access to the lower portals of the diversion tunnels for the enlarging operations, considerable open-cut excavating, as well as scaling down of the canyon walls, was involved. The lower portal of Tunnel No. 4—the tunnel farthest from the river on the Arizona side—was the first prepared, and the initial round in the

enlargement was fired on September 21, 1931. Since the top heading had not yet been holed through from the adit, a small 12-foot bench in the arch section of the tunnel was advanced one round, and then followed taking



BERNARD WILLIAMS
Assistant Superintendent



Above—Close-up of an invert drilling crew.

Left—Invert drill carriage and trimming jumbo behind it.

off a bench 30 feet in height. This latter stage in the enlarging operations was referred to by the contractors as the "bench heading", as distinguished from the top heading discussed previously and the invert section which was removed at a later operation. Upon its completion, the opening was approximately 42 feet in height and horseshoe shaped in cross section.

After a short period of experimenting, the method adopted by Six Companies Incorporated for driving the bench heading was by means of a drill carriage or jumbo mounted on a truck chassis. An experimental rig built of timbers was first constructed, and proved to be successful. Later, several rigs of welded steel were built in the company shops and mounted on International truck chassis of long wheel base. These drill carriages were equipped with five horizontal bars, with six Ingersoll-Rand Type N-75 drills mounted on each bar. A more complete description of these drill carriages was given in a previous article of this series. One-half of the main 30-foot bench was drilled with one setting of the carriage. The truck was then moved forward and backed into position on the other half of the face while the side previously drilled was being loaded. Meantime, the wing sections on either side of the top heading were being drilled from two vertical bars. Drilling of the wings was also carried on during the mucking operations on the main bench.

Forty per-cent gelatine dynamite was used

throughout. The powder was hauled by trucks from central magazines to smaller magazines near the points of use, and thence into the tunnels as needed. Primers were prepared by powder-fitters, working in isolated houses, and were carried into the tunnels in specially designed containers. As can be seen from the diagram on page 25, primers were set from "no delay" up to "15", making sixteen delays. A 440-volt circuit, with locked safety switches outside the tunnels, was used for detonating. Careful attention to wiring the leg wires to the buses resulted in remarkably few missed holes. The finally adopted method of placing the holes in the various stages of drilling, and the firing sequence, are shown in the diagram.

Electricity at several different voltages was required in the tunnels. The shovels used power at 2,300 volts. A 440-volt circuit was provided for blasting, and a separate lighting circuit of 120-volts was maintained. The tunnels were lighted throughout by reflectors hung along the walls up to within a few hundred feet of the face. Additional lighting was provided at the various faces by portable reflectors of 1,500-watt capacity. Water was pumped for use in drilling—in

many cases directly from the river—through 2-inch pipe laid on the tunnel floor.

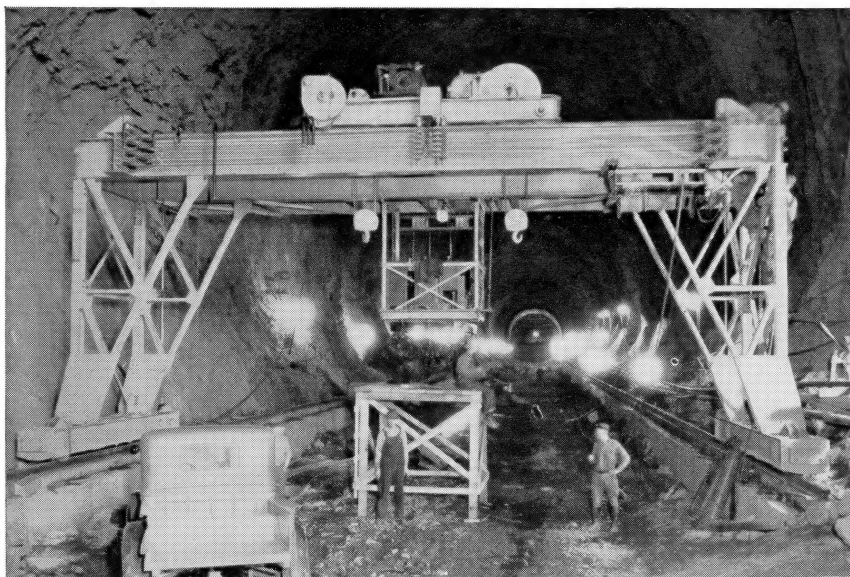
Aside from the ingenuity displayed by the contractors in the development of the exceedingly mobile drilling rig, an interesting feature was the length of steel used in drilling. Owing to the break of the rock, which in some cases left a pronounced slope from top to bottom of the main bench, 10- and 12-foot starters in the top holes were often necessary. The crews became exceedingly skillful in the handling of these lengths of steel, and also in their other operations.

During December and January, when eight faces in the bench headings were being worked, ten Ingersoll-Rand drill-steel sharpeners were in service. Shops were operated continuously in three shifts, and 30 tool sharpeners and 30 helpers were employed. These shops also cared for miscellaneous sharpening, in connection with the scaling of the canyon walls, railroad-bench and open-cut excavation, and other outside work.



FLOYD HUNTINGTON
Tunnel Superintendent

It is interesting to note that 23-foot steel was used on the drilling jumbos on the bench and invert headings. This accounts, in a large measure, for the excellent footage made per round. It required 97 tons of steel to equip



Above—Gantry crane used for pouring invert concrete.

Right—Forms ready for placing the concrete lining in invert.



all the jumbos during this period. Each jumbo, on entering the tunnel to commence drilling, carried 25 sets of steel, which weighed $5\frac{1}{2}$ tons. Each set consisted of from six to nine pieces, depending on the length of the starters.

The steel was changed on an average after each round—the sharpened steel being brought forward to the jumbo on 1-ton trucks when needed. Hollow, round, $1\frac{1}{4}$ -inch drill steel was used throughout the job; and it was estimated that the loss due to wear, sharpening, breakage, and other causes was .32 pound of steel per cubic yard of rock removed.

The average time required to back the jumbo to the face, jack it into position, attach the air, water, and electric lighting connections, and point the drills, was twenty minutes. The average drilling time on the bench heading was four hours, and the average footage per round was 16 feet. The best progress on any bench heading was made between February 1 and 8, 1932, in the upper heading of Tunnel No. 4, when 280 linear feet was driven in sixteen rounds—an average of 17.5 feet per round. The best record made in any 24-hour period on all bench excavating was 256 linear feet in eight headings on Jan-

uary 20, 1932. The best individual record for one heading was 46 feet.

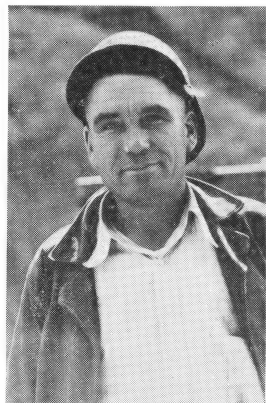
Mucking was carried on in the enlarging operations by Marion Type 490 one-hundred-ton electric shovels loading directly into dump trucks. These shovels came onto the job equipped with $2\frac{1}{4}$ -cubic-yard rock dippers; but after some experimenting a $3\frac{1}{2}$ -cubic-yard dipper was installed by the contractors. Eight of these shovels were employed, one for each heading. Five drilling jumbos were in use, four of which alternated between two headings, with one in reserve. The work was so divided that one set of dump trucks served two headings in the lower portals, with approximately 25 trucks on each side of the river. At the upper portals, about 50 trucks of larger capacity were in use, serving all four portals as mucking operations required. The trucks were equipped with specially designed rock bodies, as can be seen in the accompanying illustrations. They were of various makes and types with capacities of from 7 to 14 cubic yards.

The muck was at first removed by hand from the small bench, which was carried one round ahead of the main bench. Because of the necessary length of the bench, this oper-

ation was tedious. A caterpillar 30 tractor, equipped with a bulldozer, was later installed in the top headings, and muck from the bench was pushed off and removed by the shovel from below. Mucking operations at the main bench were facilitated by the use of caterpillar tractors equipped with a bulldozer in front and a cowdoser in the rear. After a shot was fired, the bulldozer concentrated scattered muck at the base of the muck pile. Several times during the mucking operations the bulldozer was called into use to bunch the muck for ease of handling by the shovel. The cowdoser was called into play to scrape the muck away from the bench and to keep the tunnel floor alignment true. This also facilitated the alignment of the drilling jumbo at the face of the heading.

During the firing, the shovels were moved a few hundred feet back from the face. These electric shovels made an excellent performance record throughout the operations, with remarkably few shutdowns for repairs. An average of 110 cubic yards per hour was maintained, and individual performances were as high as 200 cubic yards per hour. The average mucking time, after each round, was nine hours, and approximately 1,000 cubic yards was broken with each round. During January, 1932, as much as 16,000 cubic yards, solid measurement, was removed daily from the tunnels and hauled to spoil dumps.

The problem of the disposal of the vast amount of broken rock, or muck, was one of the most difficult faced by Six Companies



PAUL GUINN
Assistant Tunnel Superintendent



B. A. PETERS

LEIGH CAIRNS

PETE HANSON

FRANK BRYANT

These four "master muck movers" served as traffic managers for blasted materials.

Incorporated. Under the specifications of the contract, no material could be dumped into the river. Disposal areas were designated in side canyons; and where these were not available the muck had to be hauled up the side of the canyon walls on roads cut from precipitous cliffs. Steep grades of necessity prevailed. The distance that muck was hauled at the lower portals was one-half to one mile. To reach one disposal area, a 380-foot truck tunnel was necessary. At the upper portals, muck was hauled in dump trucks for a part of the time and dumped directly into 30-cubic-yard side-dump railway cars and hauled upstream approximately two miles to be used in widening the railway grade into the canyon.

The rock encountered in driving the diversion tunnels has been characterized as ideal for these operations. It is volcanic in origin, and geologically determined andesite tuff breccia. The rock is easily drilled; and when properly loaded breaks so that it may be conveniently handled by shovels. The rock is referred to by mining men as "dead". It requires accurate placing of the holes, but breaks remarkably true. No major faults were encountered, and such small seams as developed were all closed. No heavy ground was met, and no spalling or air-slacking developed—the tunnels standing through their entire lengths without timber support of any description. No water was found in any of the top headings, and only a small amount during the excavation of the bench headings. Some seepages occurred during the excavation of the invert, especially near the portals, but these will be grouted off during the lining operations. Measurements taken after the completion of the trimming and scaling operations disclosed that, despite the rapidity with which the tunnels were driven, the average overbreak in the 56-foot section was only 7 inches.

Owing to special conditions that developed where open-cut excavations were necessitated and scaling operations were required above the tunnel portals, the dates of start-

ing the enlarging operations of the tunnels varied from September 21, 1931, to December 27, 1931. The following tabulation showing the rate of progress is extremely interesting:

	Footage Progress	Faces Worked	Cu. Yds. Excavated
September.....	60.5	1	4,313
October.....	625	3	42,887
November.....	1,809	6	122,455
December.....	3,848	8	255,866
January.....	6,773	8	447,018
February.....	1,958	5	83,028
March.....	1,330	2	87,780

On March 28, 1932, there remained to be driven 205 feet of bench heading out of a total of 15,909.28. The estimated total excavation from the four diversion tunnels is 1,451,369 cubic yards, there being 91.225 cubic yards per linear foot in an ideal section of the 56-foot bore, made up as follows: Top heading, 5.333 cubic yards; bench heading, 66.002 cubic yards; and invert, 19.890 cubic yards.

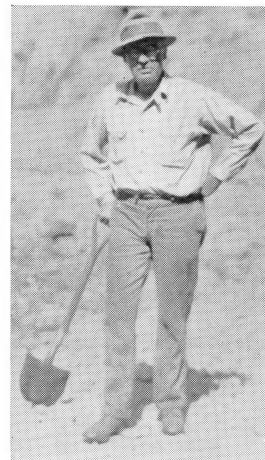
The first tunnel holed through on the bench excavation was No. 3, the one closer to the river on the Arizona side. This tunnel—3,560 feet long—is the shortest of the four; and the final shot was fired on January 30, 1932. A few days later, on February 3, Tunnel No. 2 on the Nevada side, 3,879 feet long, was holed through. Work was suspended on bench headings in the lower portal of Tunnel No. 4 on February 1, 1932; and then was started the remaining section of the invert arch necessary to complete the excavation from a horseshoe section to a complete circle. Immediately

after the bench heading was finished, invert excavation was taken in hand on both upper and lower portals of Tunnels Nos. 2 and 3. The bench excavation was continued on the upper heading of Tunnel No. 4, which was holed through on March 3, 1932.

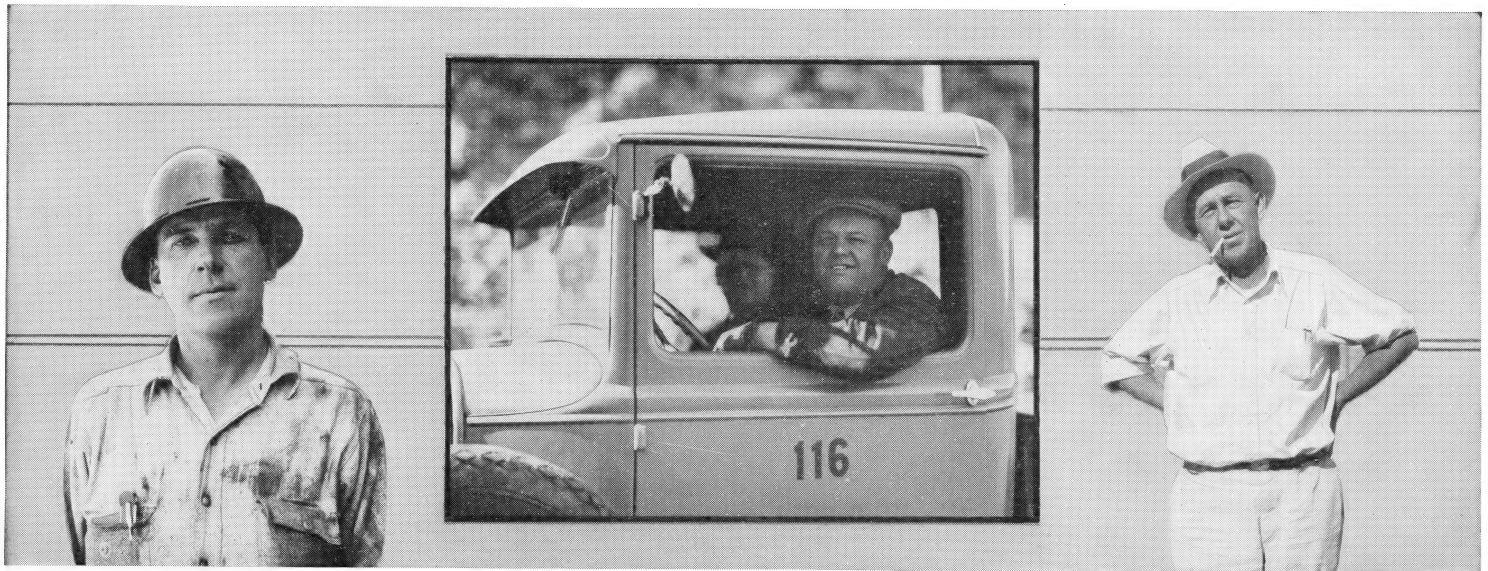
The final enlargement of the tunnels is being completed in two operations. While the invert section is being excavated, the trimming and scaling of the tunnel walls to remove the projecting rock is carried on. The removal of the invert section is a similar operation to that on the bench heading. The same drilling carriages with the top part removed and with two folding wings built on either side are used for this purpose. Drills are mounted on the wings, which form a bar, curved on a 28-foot radius, the whole of the invert section thus being drilled in one operation. During February, 1,993 linear feet of invert was removed, and in March, 5,692 feet. Six faces were worked, and 152,931 cubic yards of muck was removed out of an estimated total of 316,604 cubic yards.

The operation of trimming or scaling rocks projecting within the clearances allowed is accomplished by a trimming jumbo, and is carried on coincidentally with, and a short distance ahead of, the invert excavation. A horse-shoe-shaped steel framework is erected in each tunnel. This framework has an outside diameter of 50 feet, and is mounted on wheels traveling on 90-pound rails laid true to line and grade. Platforms are erected at different elevations on the framework,

and drills are mounted on bars at various points. The projections within the minimum allowable clearance are thus easily determined, and, when necessary, short holes are drilled and protruding points blasted on to



TOM REGAN
Assistant Tunnel Superintendent



"SI" BOUSE, Master Mechanic

"MORT" LEDERER, Sup't Motive Equipment

C. A. HARRIS, Chief Electrician

Three important personages in the tunnel-driving organization.

the floor, where the muck is removed by the invert operation, which follows.

Ventilation was supplied in the adits and top headings by Roots blowers, discharging air through 18-inch pipes at the rate of 8,000 cubic feet per minute. During the driving of the main bench headings, a strong current of fresh air was drawn in through the 10x8-foot adits, forced through the 12x12-foot top headings, and discharged into the enlarged tunnels by pressure fans with a capacity of 35,000 to 120,000 cubic feet per minute—the air being introduced in the top of each tunnel, aiding the natural air currents from the portals.

Tests showed that there was a natural air movement of 1 to 2 feet per second from the portal toward the face in the bottom half of each large tunnel, and one of similar velocity in the opposite direction in the upper half. These natural currents were the result of a temperature difference between the atmosphere outside and the warm rock inside. A striking example was the relatively rapid up-draft always present at the face of a newly

broken down muck pile.

The introduction of fresh air through the top headings accelerated the natural air currents and maintained a cool, clean, and pleasant working condition for the muckers. Tests showed that, under working conditions, activities could be resumed in five minutes after blasting with perfect safety and comfort; and the first truckload often went out fifteen minutes after the shot. Natural convection took the powder smoke to the vaulted roof and allowed men and equipment to move in under it. Then the accumulated gases were forced out by the combined action of natural and forced draft.

All the workings, involving truck operations, were thoroughly and periodically checked for air pollution. The degree of vitiation, particularly with relation to carbon-monoxide gas, was insignificant in comparison to that of vehicular tunnels, particularly where these have a definite sag, such as in the Holland tunnel.

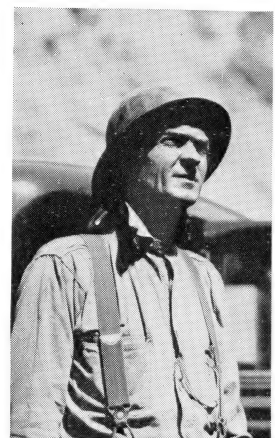
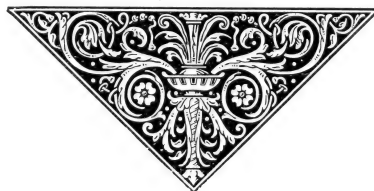
During February, 1932, a flash flood in the

Colorado River, amounting to approximately 50,000 cubic feet per second, topped the temporary embankments and flooded the tunnels. Damage was nominal; and work was suspended for several days while the tunnels were pumped out and the deposit of slime and silt was removed.

During the driving of the main bench headings, a crew of approximately 80 men was required in each heading. The crew on the drilling jumbo consisted of 22 miners, 21 chuck tenders, five nippers, one safety miner, and one drilling foreman or shifter. In addition, two crews of fifteen men each were engaged in drilling the wings on either side of the top heading. The mucking crew consisted of a shovel operator, and oiler, and a pitman. In addition to the foregoing, electricians, pumpmen, powermen, and superintendents operated in more than one heading. The daily wages of the jumbo and mucking crews were as follows: miners, \$5.60; chuck tenders and nippers, \$5; shovel operators, \$10; oilers and pitmen, \$5.

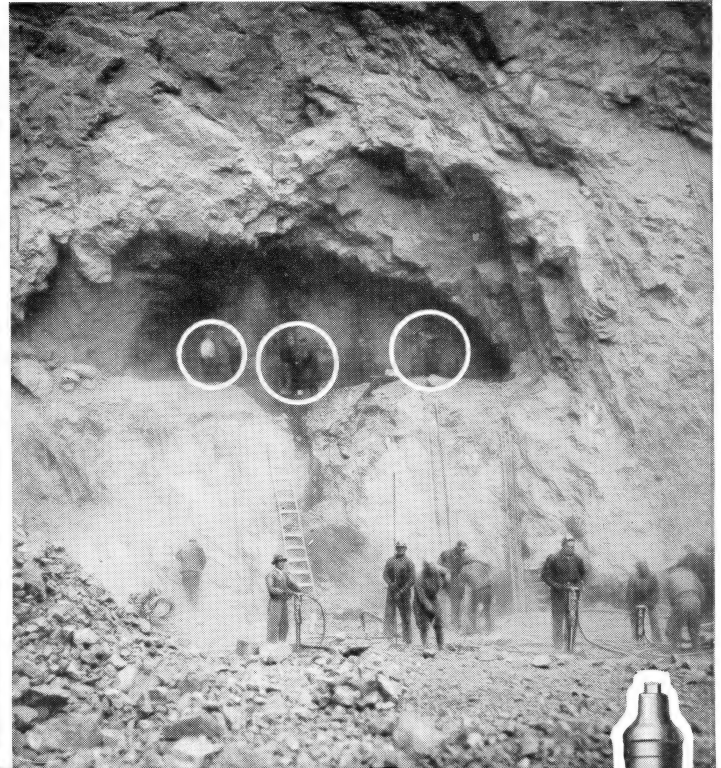
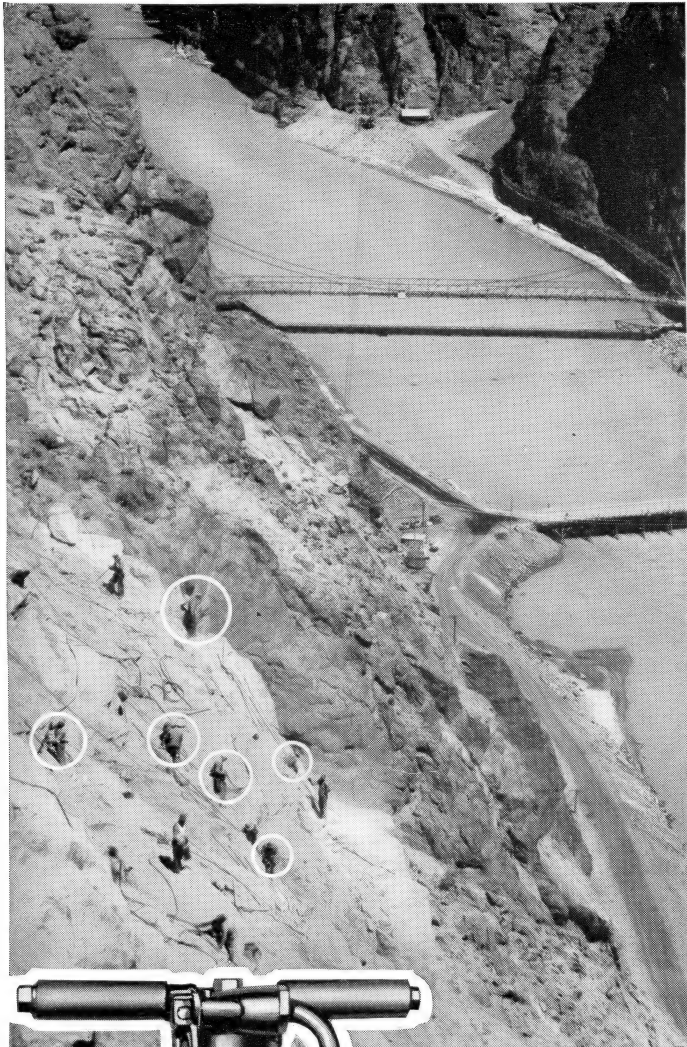


JACK LAMEY
Assistant Tunnel Superintendent

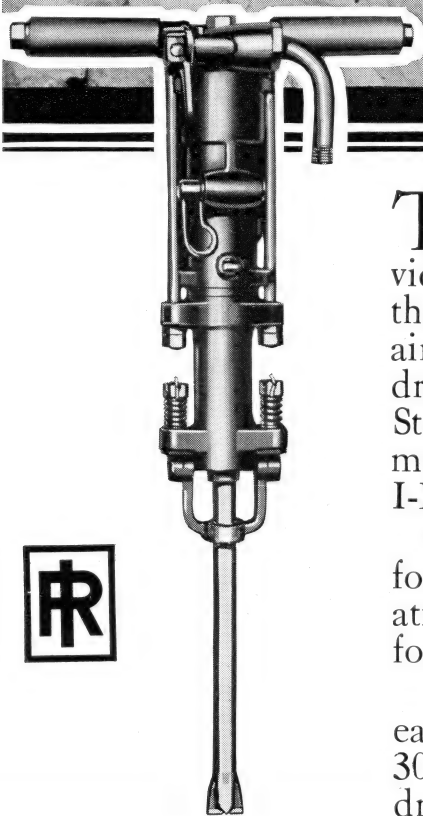


C. T. HARGROVES
Assistant Tunnel Superintendent

Every Rock Drill at the Hoover



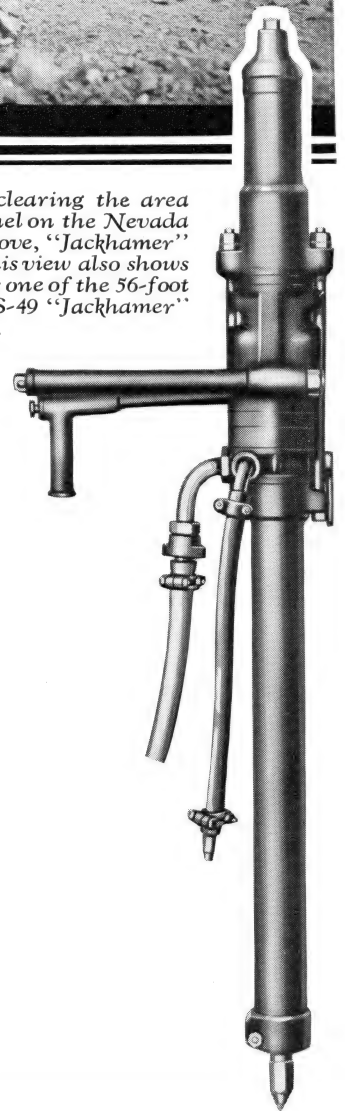
At left, "Jackhammer" drills clearing the area where the 56-foot spillway tunnel on the Nevada side will have its opening. Above, "Jackhammer" drills at work leveling-off. This view also shows the start of the top heading for one of the 56-foot diversion tunnels. Below, the S-49 "Jackhammer" and R-51 "Stopehamer" drill.



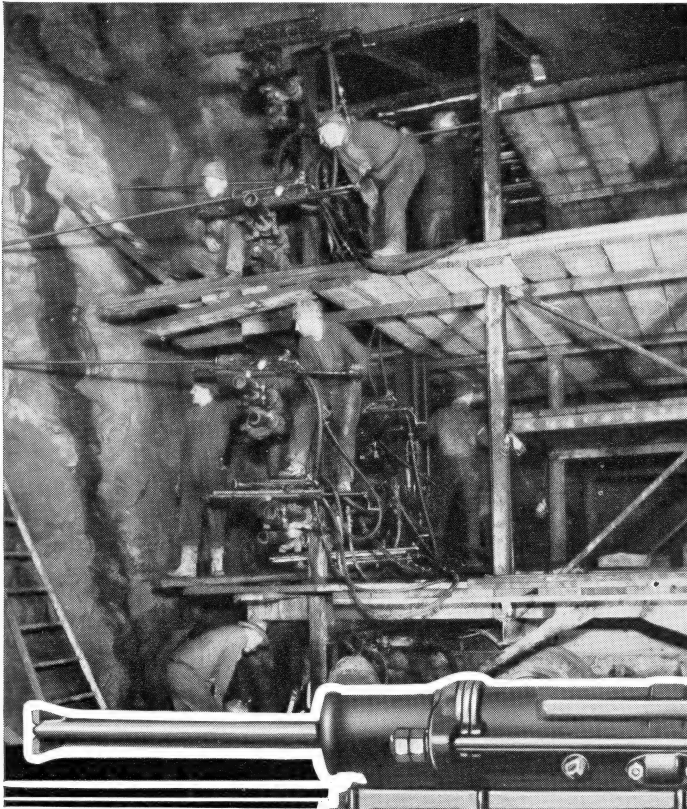
THERE are approximately 500 individual tools or machines employed on the Hoover Dam which are driven by air. The great majority of them are rock drills of the "Jackhammer", Drifter, or Stoper type. All are of Ingersoll-Rand manufacture operated from a battery of I-R compressors.

The S-49 "Jackhammer" was selected for highway, railroad, and scaling operations, and for facing openings for the four diversion tunnels.

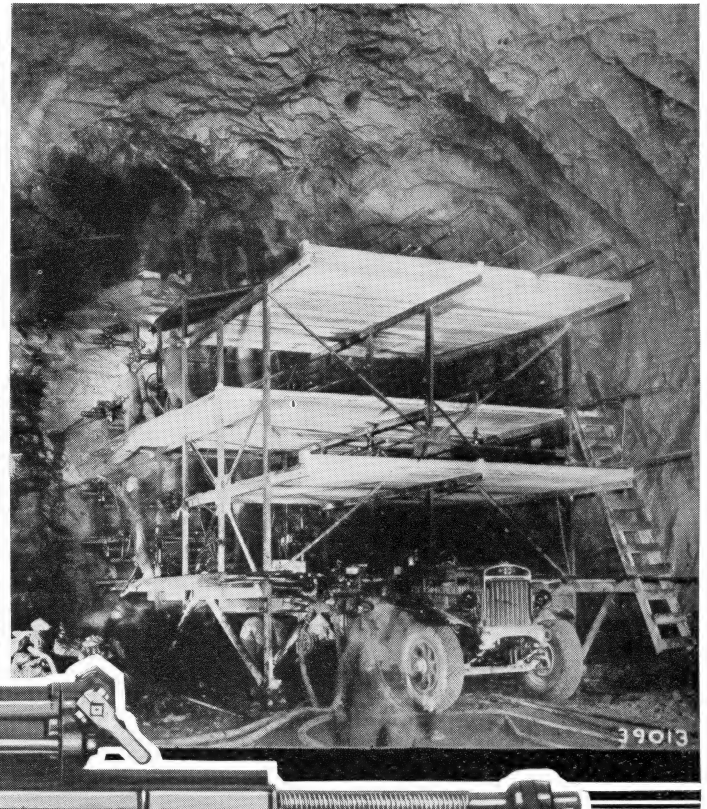
N-75 Drifter drills were used to drive each of the four diversion tunnels. 24 to 30 of these drills were mounted on rock drill carriages for the rapid drilling of the



Dam is an Ingersoll-Rand



The drill carriage or "jumbo" at a tunnel heading. Drillers are pointing their machines preparatory to starting a round.



A carriage mounted on its 5-ton truck, in position for drilling one side of the 56x30-foot bench. In the center is shown the N-75 Drifter Drill.

headings. These rock drill carriages enabled Six Companies Inc., to make an enviable record for such work.

I-R "Stopehamer" drills were used principally in raising inclined shafts from the diversion tunnels which will serve as spillways to take care of excess water in the reservoir without the necessity of running it over the top of the structure.

Among the miscellaneous I-R air tools are paving breakers, sharpeners, hoists, clay diggers, pneumatic drills, riveting hammers, chipping hammers, grinders, etc.

Ingersoll-Rand rock drills, compressors, and other equipment were chosen for this huge undertaking because of the consistent reliability they have shown for more than half a century in world-wide service.

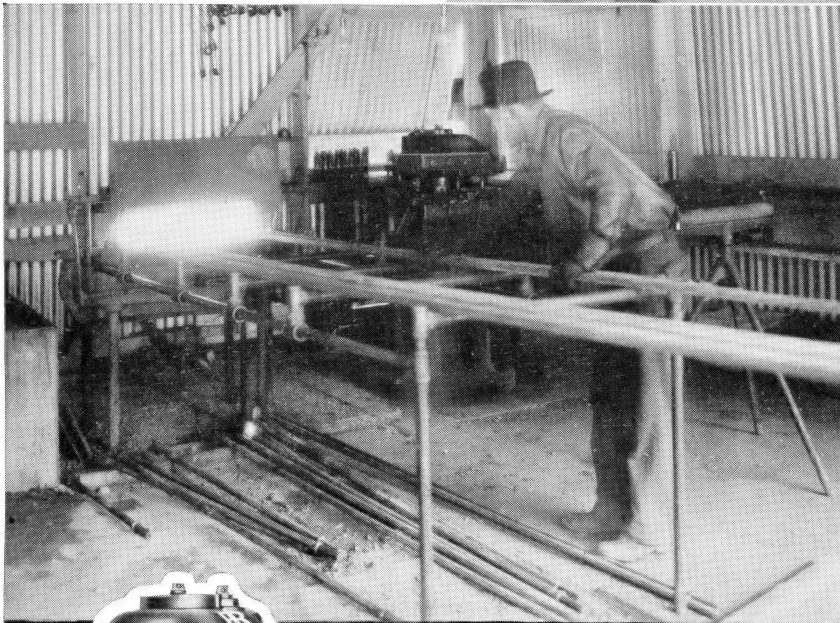
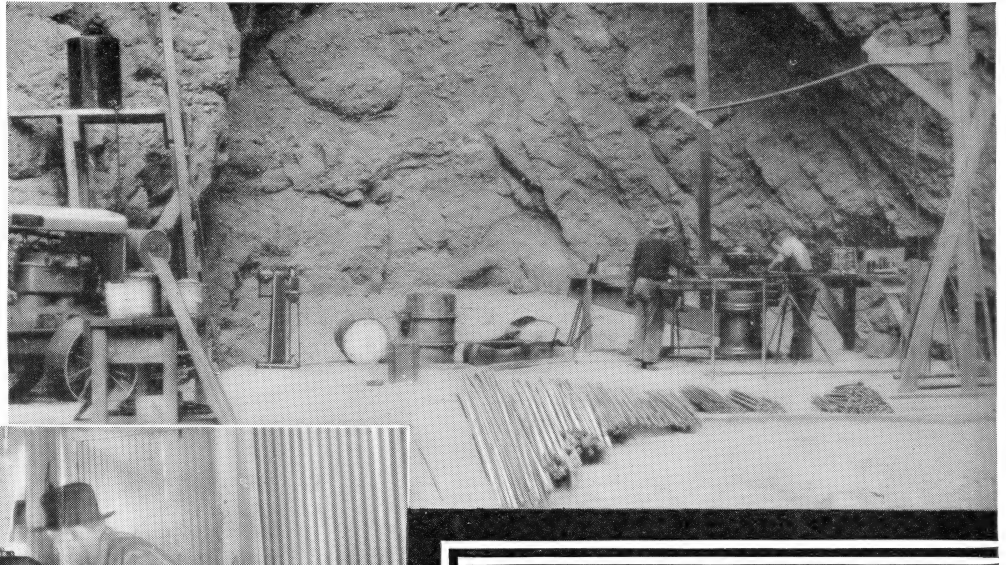
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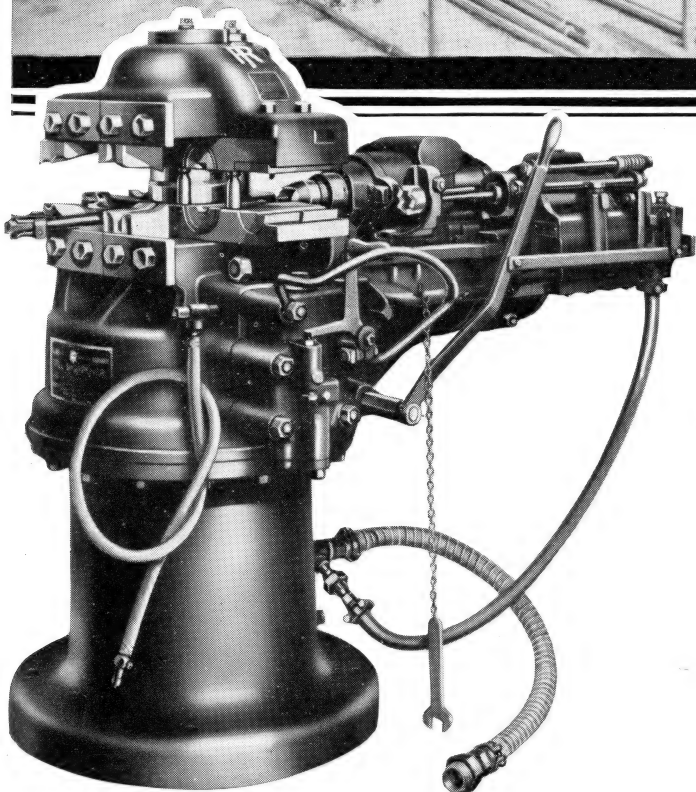
Ingersoll-Rand

77-RDM

I-R Blacksmith Shops at the Hoover Dam



Above, one of the first blacksmith shops to be put in operation. Left, a close-up view of another shop, showing sharpener and oil furnace in operation. Below, the No. 50 sharpener that is so widely used in all parts of the world.



AT the peak of the drilling operations at the Hoover Dam, there were as many as ten completely outfitted blacksmith shops for reconditioning the great amount of drill steel required for the job. Many thousands of bits and shanks were reconditioned every 24 hours during January, 1932, when the work in the tunnels was being pushed at top speed.

I-R sharpening equipment was used in each of these blacksmith shops. It included a No. 50 drill-steel sharpener, a No. 26 oil furnace for heating the steel, a No. 8 grinder for squaring shanks, and a No. 6 drill for opening plugged steel.

INGERSOLL-RAND COMPANY

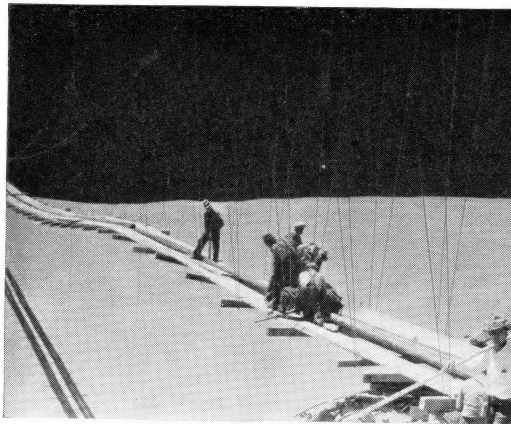
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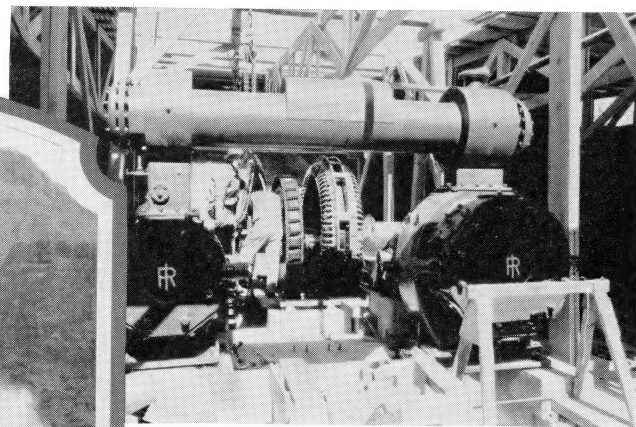
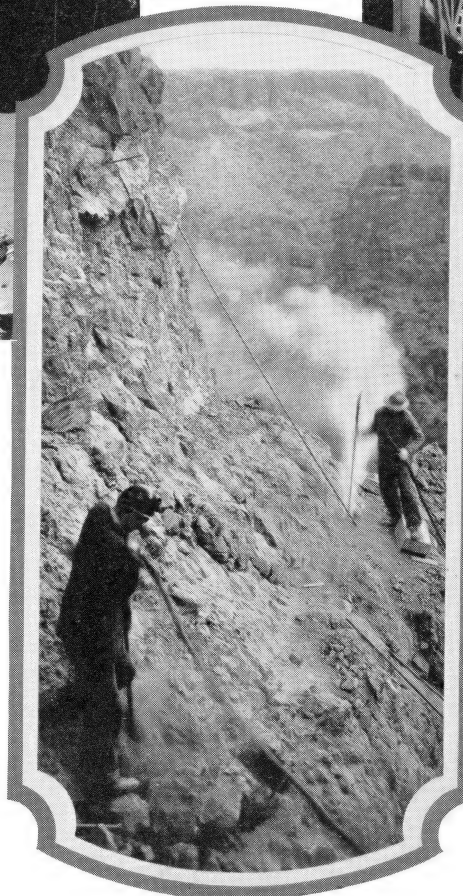
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155-LDS

Ingersoll-Rand



Laying an air line across the Colorado River on a suspension foot bridge.



Erecting a Class PRE compressor—one of five such machines on the job.

THE gigantic engineering and construction drama being enacted within the sheer walls of Black Canyon calls for many players, both human and mechanical. Various tools and machines of diverse sorts have already assumed important roles, and many others will attain prominence as the spectacle moves along toward its finale. No one of them, or no dozen of them for that matter, can, however, be given sole credit for the remarkable progress being made. All are important, not of themselves, but in conjunction with the others. Teamwork is paramount, but each contributor to the unison of effort that gets things done is as vital to the general scheme of operations as the strength of each individual link is to the power of a chain.

Keeping these things in mind, it is still possible to truthfully say that the rock drill, more than any other one class of tool or machine, has been the principal performer during the early stages of the work. It came into play at the very outset, and has been continually in the forefront of things ever since. Thousands of cubic yards of rock had to be removed by drilling and blasting in carving out the highways and railroad lines required to reach the canyon proper in order that work might begin in earnest. Long before these avenues of approach were in service, however, the advance guard of dam builders had floated down the river itself and established a meager foothold from which to start the first diversion tunnel adit, as related in the previous article. Soon afterwards the first of the scores of "scalpers" with their "Jackhammers" took up precarious perches at various points along the canyon walls to clear away loose and projecting rocks and to open up tunnel portals and other excavations. Then came the actual drilling of the 56-foot diversion bores. Meanwhile, a great amount of miscellaneous drilling was going on, so that literally hundreds of drills were in use virtually all the time during the first year after Six Companies Incorporated took active hold. At one time as many as 1,200 men were engaged in operations having to do with drilling, blasting, and moving muck.

Since compressed air is the breath of life to the rock drill, it naturally follows that a compressor installation of considerable size

Construction of the Hoover Dam

Compressed Air Plays a Part of Vital Importance in this Huge Undertaking

COPELAND LAKE

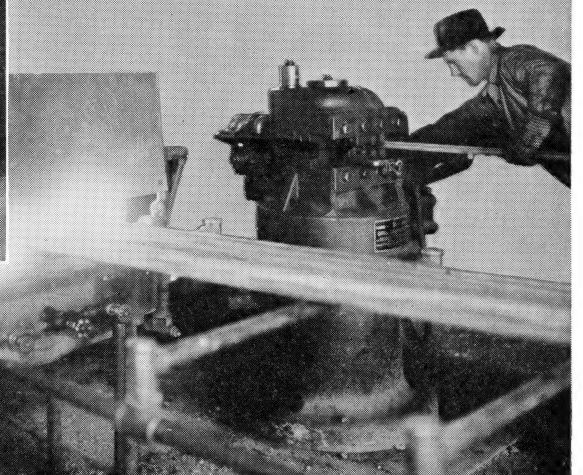
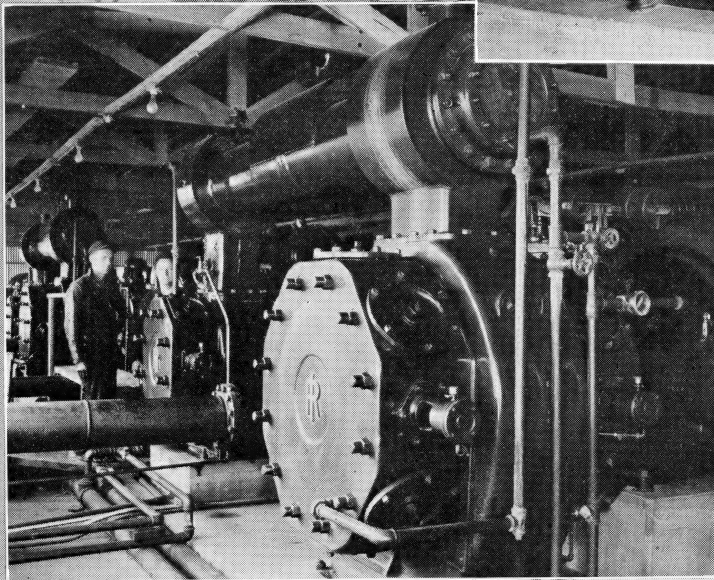
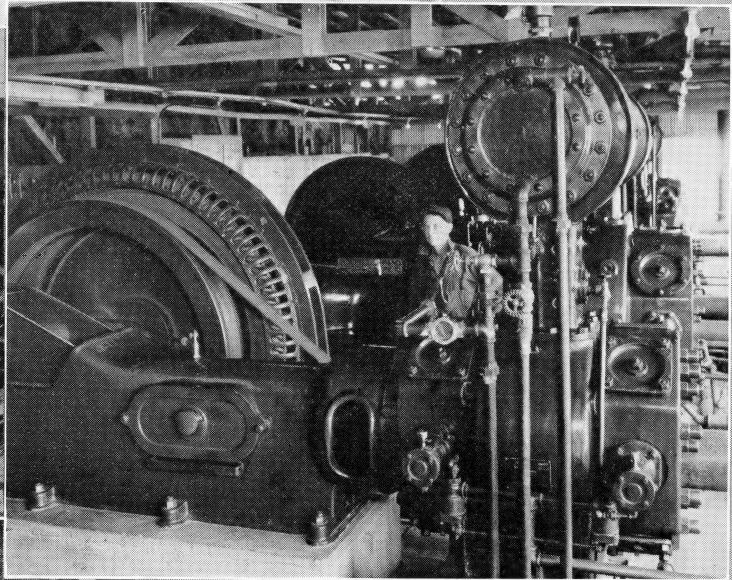
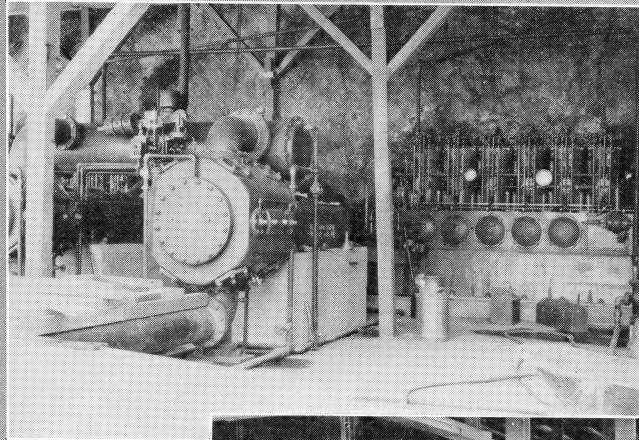
was required. When the matter of such equipment was first taken under consideration it was estimated that approximately 25,000 cubic feet of air per minute would be needed, and plants aggregating that capacity were contemplated. Actually, however, the heaviest drilling schedule to be encountered during the life of the contract was carried out with a total air supply of 16,195 cubic feet per minute.

Because so much depended upon an adequate and sustained volume of compressed air during the initial stages of the work, Six Companies Incorporated weighed carefully the selection of the machines that were to be called upon to keep the program of rock drilling moving at a fast pace 24 hours a day with scarcely a break. In the course of the

consideration it was decided that it would be advantageous to buy all the equipment required from one manufacturer so as to reduce negotiations to a minimum, to centralize the responsibility for installation and functioning of the compressors, to keep the necessary stock of spare parts low, and to simplify the duties of operation, care, and maintenance. It was also determined that it would be desirable to standardize, as far as possible, with respect to types or models and sizes. By so doing, spare parts would be largely interchangeable among the various units, and the problems of operation, care, and maintenance would become proportionately simpler.

Obviously, the primary demand was for compressors that would perform efficiently and that would, moreover, stand up under the rigorous service conditions that were bound to be imposed upon them. With a view to making a choice that would satisfy these vital demands, those charged with the responsibility of purchasing the air equipment gave close attention to the past records of the various makes of compressors which were being offered them.

In addition to the foregoing factors there was, however, another point which had to be taken into account in connection with the plans for the air plant. This had to do with the scheme which had been devised for cooling the concrete in the great dam which will some day stay the rush of the Colorado River. As is well known, the chemical processes which take place during the setting of concrete are accompanied by the generation of much heat. This heat has the effect of expanding the mass, which calls forth the reciprocal action of contraction when the heat is given up. When large blocks of concrete are poured at a time, this inevitable contraction produces fractures which weaken the structure. To obviate these difficulties, it is the universal practice to rear concrete dams on a sort of stagger system—that is, to build them progressively in sections or columns which are carried upward by easy stages. Adjacent columns are poured at different intervals, and the intervening spaces are left open for sufficient periods to facilitate the cooling of the concrete by providing radiating



At the top is one of the diesel-engine-driven compressors used until electric power became available. Next below it and at the left are two Annis filters on the air intakes of compressors. At the right, and also below, are views in Compressor Plant No. 3. At the bottom are a No. 26 oil furnace and a No. 50 drill-steel sharpener in action.

surfaces exposed to the air on all four sides. In effect, the whole area to be concreted is checkerboarded, and the squares are built up a little at a time with no two squares having sides in common being poured simultaneously. Such a system insures a minimum of shrinkage and compensates for such contraction as does take place by setting up joints which can afterwards be sealed tight with grout.

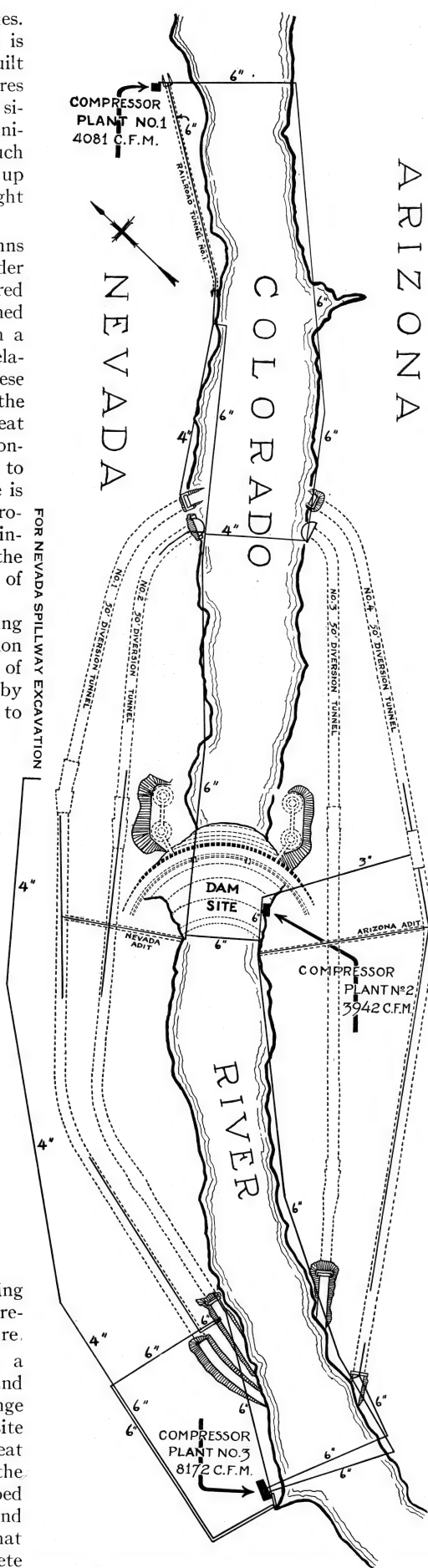
As the gaps between alternating columns in the same horizontal plane cannot, under customary methods of procedure, be poured until the major portion of their contained heat has been dissipated, the progress on a dam as a whole is necessarily slow. On relatively small structures the sum total of these delays is not of much consequence, but in the case of the Hoover Dam, with its great monolith of 3,400,000 cubic yards of concrete, it would, in the aggregate, amount to a tremendous period of time (the estimate is 200 years and more) and have the result of prolonging the construction, correspondingly increasing the expense, and postponing the date when the structure would become of service and value.

Accordingly, in the interest of quickening natural processes, the Bureau of Reclamation engineers specified that artificial cooling of the concrete should be brought into play by the contractors. It is not our purpose to here describe how the dam will be assembled, but rather to sketch the essential features of the projected plan for cooling the concrete because of the bearing it had on the selection of the air-compressing equipment.

The specifications require that after any portion of the concrete in the dam (and tunnel plugs) has set for a minimum period of six days it shall be cooled by removing the excess heat above 72° F. This is to be done by circulating water of requisite coolness through the concrete by means of a system of pipes. This involves the provision and operation, by the contractor, of a complete refrigerating plant.

To carry out this scheme, there will be needed a network of 2-inch piping aggregating 800,000 linear feet, or roughly 150 miles. This will be assembled in the form of loops or series of loops ranging up to a maximum length of 1,600 feet. Where pipes cross contraction joints they will be linked by expansion-type couplings. This piping will be embedded in the concrete and will remain a permanent part of the dam structure.

When poured, the concrete will have a temperature somewhere between 40° and 100° F. Because of the wide seasonal range in the natural temperature at the dam site—from 25° to 125° F.—the amount of heat that will have to be extracted to lower the temperature of the concrete to the prescribed 72° will vary greatly as between summer and winter. The average temperature rise that will result from the setting of the concrete will be 40° above that at which it will be placed. The amount of heat that will have to be removed is about 700 B.T.U.'s per de-



The compressor plants and principal air delivery lines.

gree per cubic yard of concrete. The estimated quantity of heat to be extracted from each cubic yard of concrete during each month of the year, and the time that will be required to do this, are shown in a table, on a following page, which is from specifications prepared by the Bureau of Reclamation. It is to be noted that the actual amounts may vary considerably from the estimates in any one year, as the figures are based on average natural temperatures.

It is provided that the refrigerating plant shall have a capacity sufficient to reduce from 47° to 40° the temperature of a flow of water of 2,100 gallons per minute. The water entering the cooling pipes shall not have a temperature lower than 35°, and may leave the embedded pipes at any temperature between 42° and 65°. The quantity of cooling water circulated may vary from 350 to 2,100 gallons per minute.

It can be realized from the foregoing facts that the contractors had in mind something besides the provision of an adequate air supply when they considered the purchase of compressors. They were concerned with obtaining machines which would not only prove efficient, reliable, and economical as air producers but which could also be readily converted, as needed, into refrigerating units.

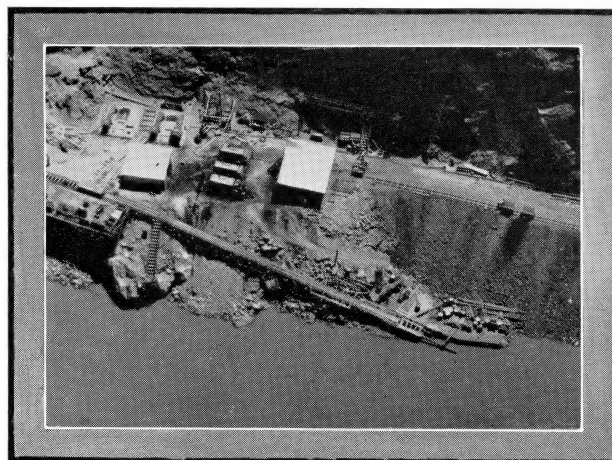
After due investigation, they selected Ingersoll-Rand electric-driven compressors equipped with clearance-valve control. In all, eleven machines were purchased. Five of them are Class PRE-2 units, each of 26&16¼x18-inch size and having a piston displacement of 2,195 cubic feet per minute. The six others are the similar although smaller Type XRE-2 machines, each 20&12½x14 and with a piston displacement of 1,302 cubic feet per minute. All are driven by Westinghouse synchronous motors with belted exciters. When the time arrives to set up the cooling plant, the substitution of ammonia cylinders for the regular cylinders on a suitable number of these compressors will convert them into efficient refrigerating units. It is expected that only the XRE machines will be used for this purpose, and that not all of them will be required.

To supply air on the job, there were established three compressor plants, the locations of which are shown on the accompanying map, together with the principal air delivery lines. It will be noticed that although the plants were not close together—the extreme distance being some two miles between Plants Nos. 1 and 3—all were connected by the piping system.

As told in the previous article, Plant No. 1, at the upper end of the canyon, was the first installed. Until electric power became available in the early summer of 1931, the two Type XRE units which it then contained were operated as belted machines with power furnished by two Atlas diesel engines. Plant No. 2, near the adit leading into the diversion tunnels on the Arizona side of the river, was the second to be set up, and it consisted of two Class PRE machines. Plant No. 3, just below the lower portals of the Nevada diversion tunnels, was the last to be erected, but became the largest of the three, with a



Above is Black Canyon as viewed from the top of the Nevada cliff and downstream from the dam site. The benches at the river edges were built up of muck taken from the adits and the diversion tunnels. The dam will rise at about the line where the lowest bridge spans the Colorado.



Left—Compressor Plant No. 2 as it appeared from above during erection. In the upper left-hand corner can be seen both frames of one machine and one frame of another one. Below them and at the right are three portable compressors. This plant is at the right of the river in the picture above.

capacity of approximately 8,172 cubic feet per minute. Plant No. 2 had a capacity of 3,942 cubic feet per minute. Plant No. 1 had an initial capacity of 2,210 cubic feet per minute, which was later increased to 4,081 cubic feet per minute through the addition of a Class PRE machine.

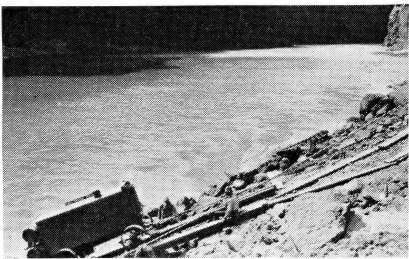
With the exception of the two Type XRE machines in Plant No. 1, all the compressors were served by I-R Class HM tubular-type aftercoolers. These coolers added to the efficiency of the drills by eliminating troubles arising from moisture in the air lines. To further guard against preventable troubles in the air system, the compressor intakes were equipped with Annis air filters of the type which can be cleaned with an air blast without taking them out of service. Circulating

water for the compressors was supplied by Cameron Motorpumps, which combine a motor and a centrifugal pump in one compact casing. Two such pumps were installed in each plant.

Since the several installations were of a temporary nature, and as the chief concern of the contractors was to get the compressors operating, no effort was made to erect model plants from the standpoint of appearance. The machines were set up in the open, and rough buildings were later constructed

around them. The piping was chosen on the basis of sizes available rather than of which were preferable to make a neat-looking job. Six Companies Incorporated asked only that

the machines function properly and keep the drills pounding away at the rock; and the record of the drilling accomplishments shows that they were given no cause for disappointment on this score. The air was discharged from the compressors at 105 pounds pressure, and was delivered to



Snaking a portable up a steep slope.

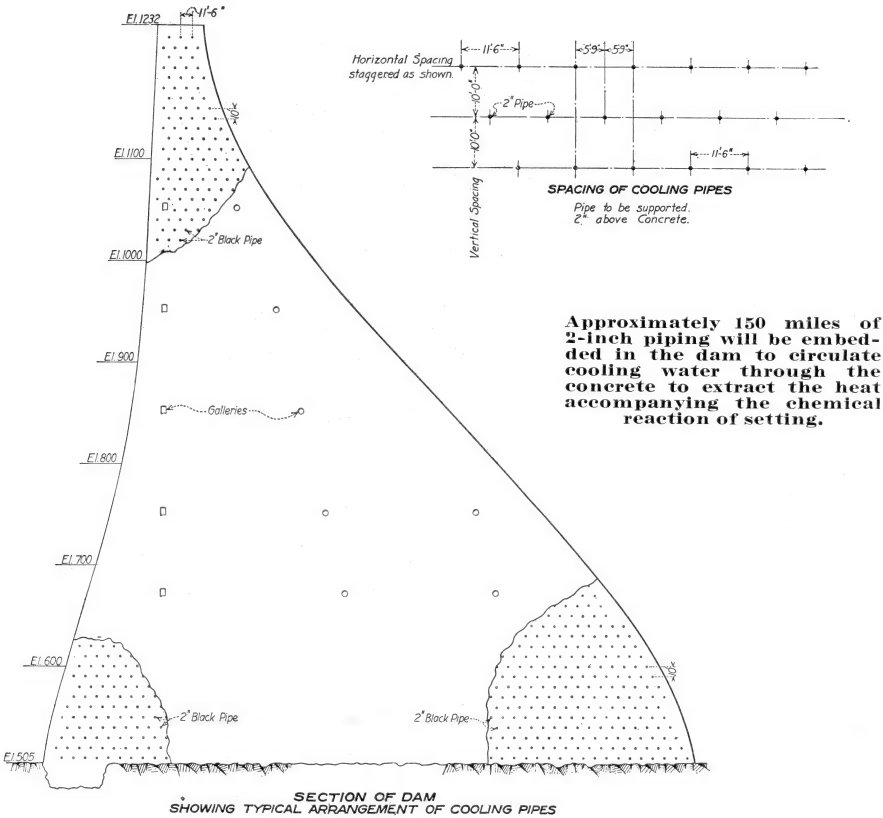
points of work on the spillways as much as a mile away at 80 to 85 pounds. Within the tunnels the pressure seldom was below 90 pounds.

Most of the compressors were installed during the torrid season of 1931, at a time when it was impossible to handle metal in the sun with the bare hands. On more than one occasion gasoline, which was being used to clean small parts, caught fire through spontaneous combustion. The first two machines to be set up were floated down the river on barges. Rock had to be blasted away at the foot of a cliff to secure enough level space to erect them; and they were snaked up the steep slope from the river with block and tackle. Plant No. 2 occupied ground reclaimed from the river by filling in at the base of the cliff with spoils from the first of the adits, which was started with air from portable compressors. The units installed there also were floated down the river.

During the period of approximately a year that they furnished air for the tunnel drill

HEAT UNITS TO BE EXTRACTED FROM CONCRETE TO ACCELERATE SETTING

	MEAN MONTHLY TEMPERATURE	MAXIMUM TEMPERATURE OF CONCRETE	HEAT TO BE EXTRACTED	B.T.U.'S TO BE EXTRACTED PER CU. YD.	COOLING WATER MUST BE APPLIED
	<i>Fahrenheit</i>	<i>Fahrenheit</i>	<i>Fahrenheit</i>		<i>Months</i>
January.....	52.0°	92.0°	20.3°	14,200	1.14
February.....	57.2°	97.2°	25.5°	17,900	1.33
March.....	63.6°	103.6°	31.9°	22,400	1.60
April.....	71.2°	111.2°	39.5°	27,700	1.83
May.....	78.6°	118.6°	46.9°	32,900	2.06
June.....	87.6°	127.6°	55.9°	39,200	2.28
July.....	93.8°	133.8°	62.1°	43,500	2.40
August.....	91.9°	131.9°	60.2°	42,200	2.37
September.....	83.0°	123.0°	51.3°	35,900	2.17
October.....	70.8°	110.8°	39.1°	27,400	1.83
November.....	59.4°	99.4°	27.7°	19,400	1.39
December.....	51.5°	91.5°	19.8°	13,900	1.10
Average.....	71.7°	111.7°	40.0°	28,000	1.79



ing, the compressors were called upon to operate through a temperature range from around 125° in July to as low as 14° during the winter. Throughout virtually all this time they ran 24 hours a day and seven days a week, and remained in service weeks at a stretch without shutting down. No repairs were required and the valves were cleaned only once. This is considered a remarkable record for compressors operating under such climatic conditions.

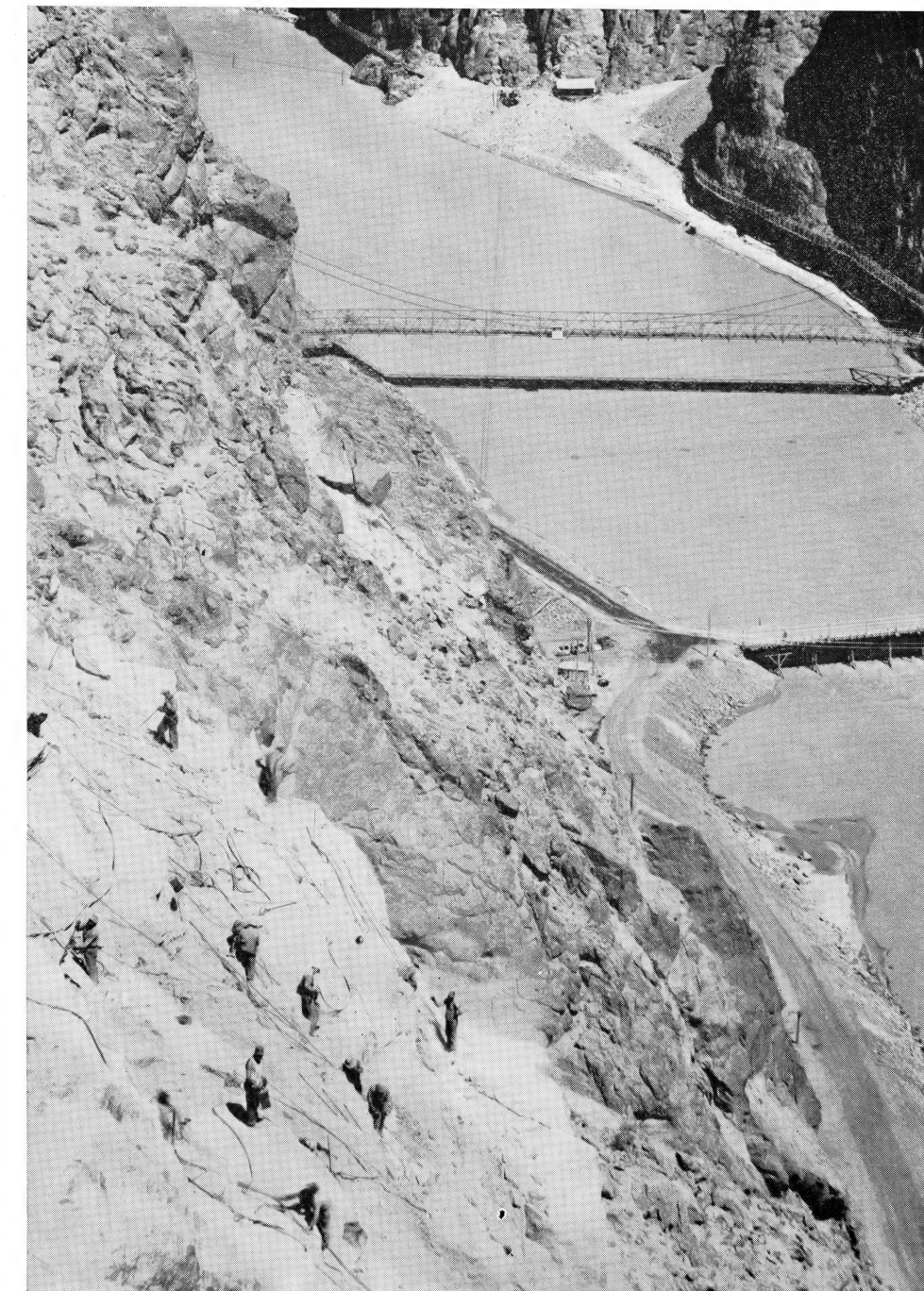
In the foregoing narrative, and in the last previous installment in this series of articles, we stressed the part that rock drills have played and will continue to play during what might be termed the preparatory stage of operations. While it is true that drilling constitutes the major use of compressed air, there are so many other ways in which this medium of power transmission is being employed that our present account should at least mention them if it is truly to portray the importance of compressed air in connection with this epoch-making enterprise. As future articles will deal with some of these functions more in detail, it is our present purpose merely to set them down for the sake of completing the record of the principal services of pneumatic power.

Seldom, if ever, has one contracting job afforded so many or such diverse applications of compressed air. An unofficial but probably quite accurate count reveals that there are approximately 500 individual tools or machines which are driven by air. The list is growing all the while, and many additional uses will no doubt be found before the contract is completed.

Besides the great number of "Jackhamers" and drifter-type drills which have been mentioned, there are about 25 stoper drills in service. These are Ingersoll-Rand CCW-11 and R-51 types, and are used principally in raising from the diversion tunnels on either side of the river the inclined shafts which will serve as spillways to take care of excess water in the dam without the necessity of running it over the top of the structure.

There are 25 Ingersoll-Rand Type CC-45 paving breakers and ten air-operated hoists at work. Both of these classes of machines perform a miscellany of services. Smaller pneumatic tools abound, among them being twelve clay diggers and varying numbers of drills, riveting hammers, chipping hammers, grinders, etc. All are of Ingersoll-Rand manufacture.

Much air is, of course, consumed by the sharpeners, oil furnaces, shank and bit punches, and pedestal grinders required in connection with the reconditioning of the vast amount of drill steel and paving-breaker steel on the job. At the peak of the drilling operations, there were as many as ten completely outfitted blacksmith shops for the performance of these services. The equipment in each shop included a No. 50 drill-steel sharpener, a No. 26 oil furnace, a No. 8 pedestal grinder, and a No. 6 drill for drilling out plugged steels. Approximately 3,500 pieces of steel were reconditioned every 24 hours during January,



"Jackhamer" men clearing the area where the 56-foot spillway tunnel on the Nevada side will have its opening. This inclined waterway is being driven by raising from the diversion tunnel with which it will connect.

1932, when the work in the tunnels was being pushed at top speed. These blacksmith shops were moved about from time to time as the drilling progressed. Not all of them are in use now that the heavy drilling schedule has been completed.

Cameron pumps of several types and sizes are used at various points for the handling of water. Many of these are pneumatically operated. Air-driven Fuller-Kinyon pumps are employed to convey bulk cement from the box cars in which it is delivered to the top of the concrete mixing plant. Gates on

the batchers, mixer hopper, and dump hopper in this plant are controlled by compressed air. Before placing the concrete lining in the invert of the diversion tunnels, it is necessary to scour the rock surfaces free of all dirt and pebbles. This is accomplished by means of compressed air used in conjunction with water.

All in all, there seems to be plenty of justification for the statement that compressed air is in the forefront of the indispensable agencies at Hoover Dam.



PRODUCTS OF INGERSOLL-RAND



Compressors, Stationary

Many sizes and types are available. Compressors can be furnished for belt and multi-V belt drive or direct drive by synchronous motor, oil engine, gasoline engine, gas engine, or steam. Units as large as 10,000 cu. ft. per minute, 100 lbs. discharge pressure, have been supplied. In addition to our standard line of machines, we are in a position to build compressors to meet special conditions. Our engineers will be glad to confer with you whenever problems arise in the compression of air or such gasses as ammonia, oxygen, hydrogen, nitrogen, carbon dioxide, sulphur dioxide, chlorine, acetylene, illuminating gas, natural gas, etc.

Compressors, Portable

Made in eight sizes for standard 100-lb. operation. Capacities range from 30 to 500 cu. ft. per minute. There are also units for high-pressure and for low-pressures. Many kinds of mountings are available. Arranged for gasoline engine, gas engine, or electric motor drive.

Turbo Compressors and Turbo Blowers

Turbo compressors for discharge pressure of 90 to 110 lbs. per sq. in. gauge in capacities ranging from 8,000 to 12,000 cu. ft. per minute. Turbo blowers for discharge pressures of 1 to 35 lbs. per sq. in., and in sizes ranging from 100 to 100,000 cu. ft. per minute.

Air Receivers

A wide range of sizes and capacities built according to the A.S.M.E. Code for "Unfired Pressure Vessels".

Air or Gas Aftercoolers

Horizontal or vertical aftercoolers for capacities up to 10,500 cu. ft. per minute, or multiple units for larger capacities.

Cameron Pumps

Centrifugal and direct-acting types in sizes suitable for every fluid-handling problem. The centrifugal line includes both single- and double-suction pumps in single- and multi-stage units. They are driven by direct-connection through flexible coupling to electric motor; steam turbine; or oil, gasoline, or gas engine.

Condensers

Equipment suitable for every condensing service. Improved design surface condensers have been built for generating units up to 165,000 KW. capacity.

Vacuum Pumps and Air Ejectors

Highly efficient vacuum pumps of both reciprocating and jet ejector types in sizes and capacities for all classes of service.

Air Lift Pumping Systems

Complete equipment for lifting water or other fluids by means of compressed air.

Rock Drills

A complete line of "Jackhamers", Drifter, Sinker, "Stope-hamer", and Submarine Drills. Sizes to meet every drilling requirement in road building, tunnelling, mining, quarrying, excavating, submarine work, etc.

Rock Drill Mountings

Many types of tripods, columns, shaft bars, quarry bars, carriages, and wagon mountings each especially suited to a particular condition.

Paving Breakers

Four sizes for cutting through asphalt, concrete, hardpan, brick and rock in road building and paving work, construction, mining, quarrying and maintenance work.

Drill Steel

IR-SKF hollow or solid drill steel is made in all the popular shapes and sizes. Also supplied in several carbon contents to meet different rock conditions.

"Calyx" Core Drills

Drills which will extract cores from 1½ to 36 inches in diameter having a capacity range of from a few inches as required in highway pavement testing, to 2500 ft. for average core drilling. Machines can also be furnished for drilling to a depth of 5000 ft. and for extracting cores up to 72 inches.

Air and Steam Hose

Several distinct types each for a specific service which will stand up under such conditions with the most economical results.

Drill Steel Sharpening Equipment

Complete sharpening equipment for the blacksmith shop including several sizes of sharpeners, shank and bit punches, oil or gas-fired furnaces, and shank grinders.

Hoists

A complete line of single-drum and double-drum portable hoists is available. Both types can be furnished for compressed air or electric motor drive. In addition, a complete line of suspension hoists is available which are air-motor driven and can be furnished with or without trolley mounting.

Pneumatic Tools

There is an I-R pneumatic tool to suit every requirement. The line includes chipping, scaling and calking hammers; coal picks and core breakers; riveters; holders-on and jam riveters; drills, reversible and non-reversible, including close-quarter types and wood boring machines; portable grinders and wire brushes; air motor hoists and stationary motors; "safety-first" portable pneumatic saws; clay and trench diggers; backfill tampers and sand rammers.

Tie Tamper Outfits

I-R tie tamper compressors are available for operating 4, 8, and 12 tampers. We also manufacture a complete line of tools for railroad track maintenance such as spike drivers, spike pullers, wood-boring drills, rail bonding outfits, track wrenches, etc.

Oil Engines

Horizontal and vertical diesel engines operating on the four-stroke cycle with solid injection of fuel oil. Sizes up to 1,200 b.hp.

Oil-Electric Locomotives

Diesel powered locomotives for railroad and industrial use.



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